Albert Shuldiner
Senior VP & General Counsel

August 2, 2004

Ms. Marlene H. Dortch
Secretary
Federal Communications Commission
445 Twelfth Street, S.W.
Washington, D.C. 20554

Re: MM Docket No. 99-325

Dear Ms. Dortch:

On July 27, 2004, iBiquity Digital Corporation ("iBiquity") submitted to the Commission recent test reports about the audio quality of iBiquity's HD Radio™ system. In order to complete the Commission's record, iBiquity hereby submits the test procedures that were followed during the test program that was discussed in that earlier filing. These test procedures were approved by the National Radio Systems Committee ("NRSC") prior to the commencement of the test program.

If you have any questions about this submission or any other aspect of the audio quality tests, please do not hesitate to contact the undersigned.

Sincerely,

Albert Shuldiner

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Digital Audio Broadcasting

Digital Performance Regression Tests Of The iBiquity Generation 3 Digital HD Radio™ System in the AM & FM Bands

Subjective Audio Evaluation Sample Preparation Procedure

February 26, 2004

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Appendices

1. Background

This document details the test procedures used for the Generation 3 testing of the HD Radio™ system. This Gen 3 testing was designed to assess the audio quality of the HD Radio system in both unimpaired and impaired conditions. The Gen 3 equipment used for this test contains the HDC audio compression technology used in the commercial implementation of the HD Radio system.

2. Related Documents

1. *Digital Audio Broadcasting, IBOC Laboratory Test Procedures – FM Band, ATTC Document No. 01-03, Revision 4.2, August 2001*
2. *Digital Audio Broadcasting, Test Bed Proof of Performance Plan, ATTC Document No. 01-20, Revision 2.0, November 2001*
3. *Digital Audio Broadcasting, Test Bed Proof of Performance Record, ATTC Document No. 01-01, Revision 2.0, November 2001*
4. *Digital Audio Broadcasting, Test Bed Daily Calibration Procedure, ATTC Document No. 01-16, Revision 4.0, October 2001*
5. *Digital Audio Broadcasting, Test Bed Daily Calibration Record of Test Results (open ATTC Document)*
6. *Digital Audio Broadcasting, Digital Performance Regression Tests of the iBiquity Digital IBOC System in the FM Band, ATTC Document No. 02-10, April, 2002*
7. *Digital Audio Broadcasting, Performance of the iBiquity Digital FM IBOC System in unimpaired Channel Conditions, ATTC Document No. 02-07B, February, 2002*
8. *Digital Audio Broadcasting, Digital Performance Regression Tests of the iBiquity Digital IBOC System in the AM Band, ATTC Document No. 02-21, July, 2002*
9. *Proposal for Subjective Evaluation of Generation 3 HD Radio Hardware, Dr. Ellyn Sheffield, December, 2003* – (Attached as Appendix A)
10. *Memorandum, To DAB Subcommittee – Test Procedures Working Group (EWG), From D. Layer, Subject, FM IBOC system 3rd generation hardware ("Gen 3") re-test.* – (Attached as Appendix B)
11. *Memorandum, To DAB Subcommittee – Test Procedures Working Group (EWG), From D. Layer, Subject, AM IBOC system 3rd generation hardware ("Gen 3") re-test.* – (Attached as Appendix C)

3. Summary of Methodology

The test plan for the Gen 3 testing was presented to the NRSC and approved in 2003. The actual testing conformed to the plan set out in *Proposal for Subjective Evaluation of Generation 3 HD Radio Hardware* by Dr. Ellyn Sheffield. Recordings of the output of five different receivers were made of specified sound samples transmitted in various analog and digital modes with the required audio processing applied. All recordings were witnessed by the designated NRSC observer, Mr. Tom Keller. Details on the treatment of test audio recordings are outlined below. The raw audio data was provided to test administrator Dr. Ellyn Sheffield for editing, leveling, and naming. The procedures for that effort are documented separately by Dr. Sheffield. The audio was then subjectively evaluated pursuant to the agreed upon procedures.

4. Test Bed Description

The HD Radio test bed located in iBiquity's Columbia, Maryland offices was used to record the audio files. The set up of the test bed is detail in the following documents:

1. *Digital Audio Broadcasting, Performance of the iBiquity Digital FM IBOC System in unimpaired Channel Conditions, ATTC Document No. 02-07B, February, 2002*
2. *Digital Audio Broadcasting, Digital Performance Regression Tests of the iBiquity Digital IBOC System in the AM Band, ATTC Document No. 02-21, July, 2002*

5. Test Methodologies

The methodologies used to record the audio for evaluation were identical to those used in previous HD Radio tests, except for the FM frequency and audio recording procedure. An FM frequency of 96.9 MHz (97.9 MHz was used previously) was selected to minimize local interference. A minor change to the audio recording mastering method was made to improve both audio quality and test efficiency. The revised audio recording methodology is set out in Section 5.1 below and replaces the methodology outlined in ATTC Document No. 01-07B, Section 3.2.1. All remaining procedures outlined in that ATTC document continued to be used for this test.

5.1. Audio Recording Methodology:

All audio recordings must be made in such a way that no significant artifacts are introduced by the recording process. This necessitates the exclusive use of an uncompressed / 44.1 kHz sample rate digital audio recording format. Additionally, the recordings must be made in a manner that lends itself to archiving and duplication.

In previous HD Radio test programs, audio was recorded to a Tascam DA-98 multi-track digital deck, using Hi-8 videotape media. This master audio was then digitally dubbed to a computer outfitted with a Lynx 1 sound card and Syntrillium Cool-Edit software.

For the Gen 3 test program, the audio was recorded directly to the PC, outfitted with Adobe Audition V1.0 (Formerly Cool Edit) Software and four Lynx-1 sound cards, the first of whose digital input was synchronized to a master word clock, all bypassing the Tascam tape-deck entirely. The PC retained the Tascam's ability to synchronize to SMPTE timecode.

The Gen 3 receiver was the only unit with an AES-EBU digital output. The analog receivers interfaced via their analog audio outputs, routing to their respective Lynx-1 sound card's analog inputs, using their internal A-D converters. It should be noted that all digital and analog recordings were made at a -20 dBfs level to accommodate any possible transients on the analog inputs.

All raw multi-track audio files were descriptively labeled for later editing, leveling, and naming by test administrator Dr. Ellyn Sheffield, as outlined in section 3.2.2 of ATTC document No. 02-07B.

6. Units Under Test

The Gen 3 exciter and receiver units were different than those used for earlier tests. The analog receivers, however, were the same physical units used previously.

6.1. Exciters

Make	Model	Serial No:	Software Version
iBiquity Digital Corp.	Generation 3	"Apple"	V 2.0.1 (HDC Codec)

Table 6-1

6.2. Receivers

Make	Model	Serial No:	Software Version
iBiquity Digital Corp.	Generation 3	"Coot"	V 2.0.1 (HDC Codec)
Delphi	09394139	89DDSTM103490265	Not Applicable
Pioneer	KEH-1900	UHH1086599UC	
Technics	SA-EX110P-K	GX9DA84758	
Sony – (FM Tests)	CFD-S22	S01-0433905-A	
Sony – (AM Tests)	CFD-S22	S01-0005122-A	

Table 6-2

6.3. Audio Processors

Audio processors were programmed with the appropriate processor settings for the source material as shown in Table 6-3 (Below)

Mode	Make	Model	Preset
FM Digital	Cutting Edge	Omnia HD-6	AC-1
	Orban	Optimod 6200	8400-HD-20-01
FM Analog	Cutting Edge	Omnia 4500	Light
			Medium
AM Digital	Orban	Optimod 6200	8400-HD-20-01
AM Analog	Orban	Optimod 9200	Classical
			Music Heavy
			News

Table 6-3

7. Summary of Recording Procedure

In order to efficiently record the designated audio cuts the selections were grouped in common transmission, impairment and audio processing modes. Concatenated master .wav files of each set of audio cuts was recorded to CD for playback through the appropriate processing/transmit/receive configurations, as shown in tables 7-1 & 7-2. In the cases indicated cuts previously recorded in the generation 2 test program were reused.

7.1. AM Master CD Recording Procedure

All master audio cuts were recorded as indicated in Table 7-1 (Below). All analog unimpaired cuts (except for Bizet) were reused from the generation 2 tests. Bizet was separately recorded . The EWF (Earth, Wind and Fire) cut indicated was inadvertently left out of the original generation 3 test source list and was separately recorded. There was no NRSC observer present for Bizet and EWF recording sessions.

CD Track	Master Unprocessed Concatenated Audio Sources (Doubled)	Digital Audio Proc.	Analog Audio Proc.	Impair-ments		Receiver / Mode					
				AWGN Core – 2 dB	AWGN Enh – 2 dB	Digital / G3 / 20 kB	Digital / G3 / 36 kB	Analog / Sony	Analog / Technics	Analog / Delphi	Analog / Pioneer
1	Ballet / Camera / Richmond / Riverdance / Clapton / CSNY / REO / Travis / Vega / ***EWF – Recorded Later, no NRSC observer present***	None	None			**X**	**X**	**X** - Cuts Previously Recorded in Gen 2 Tests (reused) NRSC observer present for Gen 2 Tests			
2	***Bizet*** (**Recorded in this session for all four analog receivers, not reused, no NRSC observer present)** / Handel / Ibert / Kyoko / FemaleA1 / FemaleC10 / MaleA1 / MaleB4	Orban 6200 8400-HD-20-01	None			**X**	**X**				
3	Ibert / Debussy		Classical	**X**		**X**		**X**	**X**	**X**	**X**
4	FemaleA1 / FemaleB2 / MaleA1 / Male B4		News	**X**		**X**		**X**	**X**	**X**	**X**
5	Santana		Music Heavy	**X**		**X**		**X**	**X**	**X**	**X**
6	Riverdance / Imagine / Fleetwood	None		**X**		**X**		**X**	**X**	**X**	**X**
3	Ibert / Debussy	Orban 6200 8400-HD-20-01	Classical		**X**		**X**	**X**	**X**	**X**	**X**
4	FemaleA1 / FemaleB2 / MaleA1 / Male B4		News		**X**		**X**	**X**	**X**	**X**	**X**
5	Santana		Music Heavy		**X**		**X**	**X**	**X**	**X**	**X**
6	Riverdance / Imagine / Fleetwood	None			**X**		**X**	**X**	**X**	**X**	**X**

Table 7-1

7.2. FM Master CD Recording Procedure

All master audio cuts were recorded as indicated in Table 7-2 (Below). All analog unimpaired cuts were reused from the generation 2 tests.

CD Track	Master Unprocessed Concatenated Audio Sources (Doubled)	Digital Audio Proc.	Analog Audio Proc.	Impairments				Receiver / Mode						
				AWGN	Multipath - Rural Fast	Multipath - Urban Fast	Terrain Obstructed	Digital / G3 / 32 kB	Digital / G3 / 64 kB	Digital / G3 / 96 kB	Analog / Sony	Analog / Technics	Analog / Delphi	Analog / Pioneer
1	Glock / Persian / Trumpet / Clapton / EWF / Grant / Shack / Simon / Travis	None	N/A	None							X Cuts Previously Recorded in Gen 2 Tests (reused)			
2	Bach / Bizet / / Kyoko / Handel / 1812 / Enya	Orban 6200 8400-HD-20-01												
3	Woman / Brokaw / Man	Omnia HD-6 AC-1												
4	Bach	Orban 6200 8400-HD-20-01	Omnia 4500 Light	X							X	X	X	X
5	Brokaw	Omnia HD-6 AC-1		X							X	X	X	X
6	Prince	None	Omnia 4500 Medium	X							X	X	X	X
7	Handel	Orban 6200 8400-HD-20-01	Omnia 4500 Light		X								X	X
8	Woman	Omnia HD-6 AC-1			X								X	X
9	Fagen	None	Omnia 4500 Medium		X								X	X
10	Persian	None	Omnia 4500 Light				X						X	X
11	Brokaw	Omnia HD-6 AC-1					X						X	X
12	Crowded	None	Omnia 4500 Medium				X						X	X
13	1812	Orban 6200 8400-HD-20-01	Omnia 4500 Light			X							X	X
14	Man	Omnia HD-6 AC-1				X							X	X
15	Cole	None	Omnia 4500 Medium			X							X	X

Table 7-2

8. Appendix A

Proposal for Subjective Evaluation of Generation 3 HD Radio Hardware

Prepared for the
National Radio Systems Committee
and
iBiquity Digital Corporation

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December 1, 2003

1 Introduction

This document describes the test environment and methodology that iBiquity proposes to perform follow-up subjective testing on the AM and FM Gen 3 receivers. Section 1 describes iBiquity's proposed listening environments, including recommendations for the AM test listening room. Section 2 describes the plan for AM subjective tests, including unimpaired transmissions (Test G) and transmissions with AWGN (Test B.1). Section 3 describes the plan for FM subjective tests, including unimpaired transmissions (Test I), transmissions with AWGN (Test B.1) and with multipath impairments (Test B.2).

In keeping with past subjective testing of the IBOC system, this test plan proposes that FM test samples will be delivered over headphones, and that AM test samples will be delivered over high-quality, near-field monitors. Historically, these were the delivery systems used in past NRSC approved tests. Thus, results from these regression tests can be put into the appropriate context, taking into consideration results from past testing. Although it has been argued that the majority of consumers listen to radio over loudspeakers, iBiquity recognizes that the difference in sound quality between unimpaired FM analog and digital at higher bit-rates may be very subtle, requiring participants to listen over the most critical delivery system (i.e., high-quality headphones) in order to be able to discern differences. However, for AM unimpaired testing, differences are somewhat larger between analog and digital recordings. Thus, since finer-grained distinctions are not the focus of this test, it is more desirable for participants to judge audio over a high-quality transmission system that most closely simulates real-world conditions. By doing so, participants will be able to judge audio samples based on the quality (and impairments) that they will encounter in real listening situations, making results more likely to emulate future consumer reaction in the marketplace. With that in mind, iBiquity has established 2 listening environments, the first suitable for loudspeaker testing, the second suitable for headphone testing.

2 Listening Environments

2.1 Listening Environment for AM loudspeaker testing

When designing a listening environment for AM testing, iBiquity's goals were:

(a) to provide a relatively quiet testing environment (under 40dBA) with minimal reverberation and other external noises that could interfere with the listening experience
(b) to provide a listening environment that was comparable to the environment used by Dynastat and ATTC for subjective testing.
(c) to provide well-lit, attractive areas that would be suitable for use with the general public
(d) to use high-quality loudspeakers to deliver audio samples to participants.

iBiquity has created 1 listening room for loudspeaker testing. The room measures 21' X 14' but the room is separated by a curtain located at 14' 11". Thus, the listening area measures approximately 14'3" x 14' 11". Background noise and reverberation measurements were taken on November 3, 2003 by an outside acoustical expert (see Appendix A)[1]. These measurements indicate that the background sound level for the room ranged from 31 to 34

[1] Although measurements were taken for 2 rooms, iBiquity intends to use only one room, identified in Appendix A as the "main listening space"

db, A-weighted, and reverberation time was 0.25 seconds at 500 Hz., indicating that the room was relatively quiet and minimally reverberant. However, two issues were noted in the acoustical consultant's report: (a) voices outside of the room were audible due to the outside door, and (b) curtains in the room were in need of acoustical upgrading. Prior to performing AM testing, iBiquity will improve the acoustical characteristics of this room by purchasing and installing a "door system" and acoustically appropriate curtains.

Genelec near-field monitors will be used to deliver audio samples during AM testing. These are high-end, high quality speakers, and are particularly well suited to close range listening. Files 7 through 31 in Appendix A describe the response curves of these monitors. These curves indicate that the Genelec monitors perform extremely well, providing even coverage with smooth frequency response. During testing, in order to optimally listen to sound samples, participants will be directed to sit in chairs located in a predetermined position and instructed not to move or relocate their chair during the course of the experiment. All samples for an experiment are stored on the hard drive of the computer which is connected to a Lucid Digital-to-Analog-Converter (DAC). The DAC is connected directly to the Genelec loudspeakers. Samples are presented to listeners via software created by iBiquity. Participants hear samples, one-by-one, and register their responses using a mouse. Figure 1 is a photograph of the AM listening room setup.

Figure 1 - Speaker Listening Room

2.2 Listening Environment for FM headphone testing

For headphone testing, iBiquity has established two listening stations, each of which include a Tremetrics sound booth (purchased from Dynastat, Inc.), an HP Vectra PC, a Lucid DA9624 digital to analog converter and a monitor. The booths are sound-treated with a measured ambient noise level <35dBA. Sound from one booth is completely isolated from the other booth. The only equipment inside each booth is a chair, a small laptop desk, a pair of headphones, and a PC mouse. These stations are located in a quiet, interior room, with a noise level measuring 34dB(A). As described in Appendix A, there are no acoustical problems associated with this room that require remediation.

As in prior NRSC-FM testing, audio samples will be presented to participants over Sennheiser HD-600 open-backed headphones. Again, all samples for the experiment are stored on the hard drive of the individual computer, connected to a Lucid Digital-to-Analog-Converter (DAC), connected directly to the Sennheiser headphones. As with AM testing, samples are presented to listeners (via software created by iBiquity) who hear samples and register their responses using a mouse. Figure 2 is a photograph of the FM listening room setup.

Figure 2 – Headphone Listening Room

3 Test Plan for AM

The AM test plan was designed to provide information about consumer reaction to iBiquity's Generation 3 hardware incorporating iBiquity's HDC audio compression technology in either core (20 kbps) or enhanced (36 kbps) mode. A comparison of Gen3 and Gen1 hardware is included in the design.

3.1 Experimental Design

One experiment will be conducted which will include unimpaired audio (Test G), and audio with additive white Gaussian noise (Test B.1). In the first segment of the experiment, participants will rate all unimpaired audio samples. They will then have a 15-minute break, and rate the audio samples with AWGN. 18 audio samples were selected for the unimpaired listening test, including 4 classical selections, 6 rock selections, 4 speech selections and 4 commercials. Six additional samples were selected for the impaired segment in order to replicate iBiquity's AM IBOC DAB Generation 2 Hardware Tests.

Table 1 lists the samples and post-processor settings to be used in both segments.

Table 1: Samples and post-processor settings for AM Tests

ARTIST	ALBUM TITLE	SONG TITLE	Digital Post-processor settings	TEST
Bizet	Carmen		Orban 8400-HD-20-01	Unimpaired
Eric Clapton	Best of Clapton	Change the World	No Processing	Unimpaired
Crosby, Stills, Nash, & Young	Looking Forward	Sanibel	No Processing	Unimpaired
EWF	Greatest Hits	Let's Groove	No Processing	Unimpaired
Handel	Messiah	Hallelujah	Orban 8400	Unimpaired
Jaques Ibert	Summertime Music for Oboe	Entr'acte	Orban 8400	Unimpaired
Moulton Labs	CriticalListening Excerpts	Kyoko Saito	Orban 8400-HD-20-01	Unimpaired
REO Speedwagon	Hi Fidelity	Keep on Loving You	No Processing	Unimpaired
Randy Travis	A Man Ain't Made of Stone	A Heartache In the Works	No Processing	Unimpaired
Suzanne Vega	Nine Objects of Desire	Caramel	No Processing	Unimpaired
Ballet Woman	Voice Over	From WTOP	No Processing	Unimpaired
Camera	Voice Over	From WTOP	No Processing	Unimpaired
From Richmond	Voice Over	From WTOP	No Processing	Unimpaired
Riverdance	Voice Over	From WTOP	No Processing	Both
Santana	Supernatural	Smoth	Orban 8400-HD-20-01	Impaired
Ibert	Summertime Music for Oboe	Entr'acte	Orban 8400-HD-20-01	Impaired
Fleetwood Mac	Tango in the Night	IGY	No Processing	Impaired
Imagine	Voice Over		No Processing	Impaired
Debussy	String Quartet in g minor	Anime et tres decide	Orban 8400-HD-20-01	Impaired
FemaleB2	Brown	The Switch	Orban 8400-HD-20-01	Impaired
FemaleA1	Austen	Northanger Abbey	Orban 8400-HD-20-01	Both
FemaleC10	Scottline	The Vendetta Defense	Orban 8400-HD-20-01	Unimpaired
MaleA1	Coonts	Hong Kong	Orban 8400-HD-20-01	Unimpaired
MaleB4	Glenn	John Glenn: A Memoir	Orban 8400-HD-20-01	Unimpaired

Table 2 describes the conditions for Section 1 (unimpaired audio), divided by receivers and genres. Table 3 describes conditions for Section 2 (audio with AWGN).

Table 2: Section 1 Design

Genre	Pioneer	Technics	Delphi	Sony	Core (20 kbps)	Enhanced (36 kbps)	FM (high anchor	AM-AWGN (low anchor)	Total
Classical	4	4	4	4	4	4	4	4	32
Speech	4	4	4	4	4	4	4	4	32
Commercial	4	4	4	4	4	4	4	4	32
Rock	6	6	6	6	6	6	6	6	48
Total	18	18	18	18	18	18	18	18	144

Table 3: Section 2 Design

Genre	Pion	Tech	Delp	Sony	Gen3 Core (20 kbps)	Gen3 Enhanced (36 kbps)	Gen1 Enhanced	FM (High Anchor)	Total
Classical	2	2	2	2	1	1	1	1	12
Speech*	4	4	4	4	2	2	2	2	24
Commercial	2	2	2	2	1	1	1	1	12
Rock	2	2	2	2	1	1	1	1	12
Total	10	10	10	10	5	5	5	5	60

*Speech will consist of 1 male and 1 female recording

3.2 Test Sample preparation

Test audio samples will be created at iBiquity for the purpose of this experiment, under supervision of an NRSC observer. For unimpaired audio, all AM analog samples will be taken from recordings made previously for the NRSC Gen2 test program. For digital audio, samples will be transmitted over unimpaired laboratory test channels through both the AM core and enhanced IBOC systems. Two reference recordings will be included in Section 1 which will act as high and low anchors. These anchors are included to allow participants to use the full range of the rating scale and minimize the changes of rating compression. The high anchor will be an analog FM audio sample recorded using the Delphi receiver; the low anchor will be an audio sample recorded using an MP3 codec at 6 kbps with added base distortion. Section 2 will also include the high anchor reference, but will not include the low anchor. Samples will be edited and leveled for presentation to participants using guidelines established and approved by the NRSC for previous tests.

3.3 Participants

Participants will be recruited from the general public, representing each of eight categories: four age groups (16-24; 25-32; 33-42; and 43-50) for each gender (male, female). Each experiment will include data from 40 qualified listeners, where qualification will be based on performance on an initial screening test and a post-hoc screening test designed to eliminate obvious outliers. Since approximately 10% of listeners are screened out from each test, tests will initially include 44 participants.

3.4 Procedures

Experiments will be conducted at iBiquity under the supervision of Dr. Ellyn Sheffield. Prior to testing, participants will complete both training and screening. Training will consist of familiarizing participants with the computer software. Screening will be conducted to ensure that listeners are reliably able to distinguish between samples. The listener's task will be to listen to 3 samples, 2 of which are the same and the 3rd substantially different (i.e., 2 CD source samples and an analog AM sample; 2 CD source samples and a sample coded at 20kbps). Listeners will be encouraged to listen as many times as necessary to make this judgment[2].

The Absolute Category Rating (ACR) method will be used in the main experiments to evaluate the subjective quality of the audio conditions. The ACR yields a mean opinion score, which is a measure of overall audio quality. As in previous NRSC testing, participants will listen to samples, one-by-one, and rate them on a 5-point scale (Excellent=5; Good=4; Fair=3; Poor=2; Bad=1).

[2] Screening in this fashion should only eliminate listeners who have real and apparent difficulty distinguishing sound samples from each other. This is not intended to screen out general population listeners in the same way double-blind, triple stimulus tests do with audio material coded at very high bit-rates.

4 Test Plan for FM

The FM test plan is designed to provide information about consumer reaction to iBiquity's Generation 3 hardware incorporating the HDC codec at 64 kbps and 96 kbps. A comparison of Gen3 and Gen1 is included in the design.

4.1 Experimental Design

One experiment will be conducted, which will include (i) unimpaired audio (Test G), (ii) audio with AWGN (Test B.1) and (iii) 3 forms of multipath (Test B2). As with the AM test, in the first segment of the experiment, participants will rate all unimpaired audio samples. They will then have a 15-minute break, and rate the audio samples with AWGN and multipath impairments. Table 4 lists the samples and post-processor settings to be included in both sections. Tables 5 and 6 describe the design for these sections.

Table 4: FM Digital Post-Processor Settings

ARTIST	ALBUM TITLE	SONG TITLE	Digital Post-processor settings	TEST
Bach	Brandenburg Concerto #5, D Major	Allegro	Orban 8400-HD-20-01	Both
Bizet	Carmen		Orban 8400-HD-20-01	Unimpaired
Enya	Shepherd Moons	Angeles	Orban 8400-HD-20-01	Unimpaired
Eric Clapton	Best of Eric Clapton	Change the World	No Processing	Unimpaired
Paula Cole	Harbinger	Happy Home	No Processing	Impaired
Crowded House	Woodface	Weather With You	No Processing	Impaired
Earth, Wind and Fire	Greatest Hits	Let's Groove	No Processing	Unimpaired
Fagen	The Nightfly	IGY	No Processing	Impaired
Glockenspeil	SQAM Disc		No Processing	Unimpaired
Amy Grant	Heart in Motion	Baby, Baby	No Processing	Unimpaired
Handel	Messiah	Hallelujah	Orban 8400-HD-20-01	Both
Medewski, Martin & Wood	Shack Man	Hermeto's Daydream	No Processing	Unimpaired
Moulton Labs	Critical Listening Excerpts	Kyoko Saito	Orban 8400-HD-20-01	Unimpaired
Prince			No Processing	Impaired
Persian Music			No Processing	Both
Paul Simon	Rhythm of the Saints	Can't Run But	No Processing	Unimpaired
Tchaikovski	1812 Overture	Track 17	Orban 8400-HD-20-01	Both
Randy Travis	A Man Ain't Made of Stone	A Heartache In the Works	No Processing	Unimpaired
Trumpet	SQAM Disc		No Processing	Unimpaired
English Woman	SQAM Disc		Omnia AC	Both
Tom Brokaw	The Greatest Generation		Omnia AC	Both
English Male	SQAM Disc		Omnia AC	Both

Table 5: Design for Section 1-FM Experiment

Genre	Pioneer	Technics	Delphi	Sony	64kbps	96kbps	CD(high anchor	AM (low anchor)	Total
Classical	5	5	5	5	5	5	5	5	40
Speech	3	3	3	3	3	3	3	3	24
Critical	3	3	3	3	3	3	3	3	24
Rock/Pop/Contemp	7	7	7	7	7	7	7	7	56
Total	18	18	18	18	18	18	18	18	144

Table 6: Design for Section 2-FM Experiment

	Classical	Rock	Speech	Total
AWGN				
Gen 1	Bach	Prince	Brokaw	3
Gen 3	Bach	Prince	Brokaw	3
Delphi	Bach	Prince	Brokaw	3
Technics	Bach	Prince	Brokaw	3
Pioneer	Bach	Prince	Brokaw	3
Sony	Bach	Prince	Brokaw	3
Rural Fast				
Gen 1	Handel	Fagen	Woman	3
Gen 3	Handel	Fagen	Woman	3
Delphi	Handel	Fagen	Woman	3
Pioneer	Handel	Fagen	Woman	3
Terrain Obstruction				
Gen 1	Persian	Crowded H.	Brokaw	3
Gen 3	Persian	Crowded H.	Brokaw	3
Delphi	Persian	Crowded H.	Brokaw	3
Pioneer	Persian	Crowded H.	Brokaw	3
Urban Fast				
Gen 1	1812	Cole	Man	3
Gen 3	1812	Cole	Man	3
Delphi	1812	Cole	Man	3
Pioneer	1812	Cole	Man	3

Test Sample preparation

All audio samples will be created at iBiquity under supervision of an NRSC observer. For the unimpaired audio quality experiment, all FM analog samples will be taken from recordings previously made for the NRSC Gen2 test program. FM digital samples will be transmitted over unimpaired laboratory test channels through the FM IBOC system at 64 and 96 kbps. Two reference recordings will be included in Section 1 which will act as high and low anchors. The high reference will be a CD source; the low anchor will be an analog AM audio sample recorded using the Sony receiver. Including a CD source reference is crucial to test whether the IBOC FM system delivers audio quality equivalent to that of a CD. The low anchor is included to allow participants to use the full range of the rating scale, minimizing the possibility of overly compressed scores. Samples will be edited and leveled for presentation to participants using guidelines established and approved by the NRSC for previous tests.

4.2 Participants

As with AM testing, participants will be recruited from the general public, representing each of eight categories: four age groups (16-24; 25-32; 33-42; and 43-50) for each gender (male, female). The experiment will include data from 40 qualified listeners, where qualification will be based on performance on an initial screening test and a post-hoc screening test designed to eliminate obvious outliers. Since approximately 10% of listeners are usually eliminated by these screening processes, iBiquity will recruit and run 44 listeners.

4.3 Procedure

Prior to testing, participants will complete both training and screening. All methodological procedures as described in AM testing will be followed.

As with AM testing, the Absolute Category Rating (ACR) method will be used in the main experiments to evaluate the subjective quality of the audio conditions. Participants will listen to samples, one-by-one, and rate them according to a 5-point rating scale (Excellent = 5; Good = 4; Fair = 3; Poor = 2; Bad = 1). Participants will listen to up to 200 sound samples, divided into 3 listening sessions.

4.4 Results

Preliminary analyses will be conducted to determine whether specific groups of participants (i.e., females, younger listeners, etc.) reacted differently to the audio samples than other groups. Statistical analyses will be conducted on MOS scores.

For Mean Opinion Scores, data will be presented in tables along with confidence intervals.

Appendix A

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November 3, 2003

Russ Mundschenk
Ibiquity Digital
8865 Standford Blvd Suite 202
Columbia, MD 21045

Re: Ibiquity Listening Room Survey

Dear:

This letter provides a brief summary of the measurements made in the Ibiquity listening spaces during my visit to the site on 29 October 2003. In all, three spaces were surveyed:

1. Main Listening Space - 21 feet by 14 feet space. Ceiling of 2x2 mineral board acoustic tiles. Walls of 1 inch cloth covered glass fiber board. Carpeting. Curtain divides the room at six feet in from window-wall. Curtain of cloth/vinyl material. Large drum kit located "behind curtain". Floor carpeted.
2. Small Listening Booth- A prefabricated Acoustic System audiometric test booth used for headset testing
3. Secondary Listening Space - small room 7 feet 21 feet. Carpeted. Walls are gypsum board with panels of Sonex distributed throughout room. Large electrical closet with bi-fold doors on one side of room.

Measurements of background sound levels and reverberation time were carried out in the Main Listening Room using a Bruel & Kjaer Type 2260 Precision Sound Level Meter/Spectrum Analyzer. Measurements of background sound levels were also made in the Audiometric Booth and Secondary Listening Space. The meter was calibrated before and after the measurements were made using a Type 4231 Acoustic Calibrator. Reverberation time measurements were made

using the internal sound source of the 2260 amplified through an Anchor Public Address monitor. The speakers in the Main Listening Space were evaluated using a Goldline Pink Noise Source played through the mixing board. Measurements were carried out at various locations in the main room to characterize the loudspeakers for response and coverage.

The measured data is provided in the Appendix. Generally background noise levels were measured with octave band resolution, and response curves of the loudspeakers were measured in one-third octaves. The data is organized as follows:

- Files 1 through 6 - Background levels in the main listening room.
- Files 7 through 11 - third octave measured sound pressure levels of pink noise played through Definitive Tower speakers (5 foot height).
- Files 12 through 16 - third octave measured sound pressure levels of pink noise played through Definitive Tower speakers (seated height).
- Files 17 through 21 - third octave measured sound pressure levels of pink noise played through Genelec speakers (seated height).
- Files 22 through 26 - third octave measured sound pressure levels of pink noise played through Genelec speakers (seated height).
- Files 27 through 31 - third octave measured sound pressure levels of pink noise played through third set of speakers (seated height).
- Files 32 and 33 - background sound levels in audiometric booth.
- File 34 and 35 - background sound levels in Secondary Listening room (with lights off).

Note that the L_{90} values are the best descriptor from which to assess background noise level measurements, and the L_{eq} values are the best to assess speaker coverage.

A-weighted background sound levels in the main listening rooms ranged from 31 to 34 dB. Levels in the audiometric booth and secondary listening room were 34 dB(A) and 35 to 36 dB(A) respectively. The loudspeakers provide even coverage

with smooth frequency response. The Genelecs appear to provide the best response.

Reverberation time in the main listening room was 0.25 seconds at 500 Hz. Times were less than 0.15 seconds in the 1000 Hz and above range and rose below 500 Hz as expected, to 0.5 seconds at 125 Hz.

Several facts were noted during my review of the spaces. Voices in the hallway outside of the room containing the audiometric booth were audible, mainly via the open door to the room. The door, which was in the room, was re-hung and it was noted that the voices (at normal speech levels) were no longer audible with the door closed. Audible noise from the electrical closet (mainly at 60 and 120 Hz) was audible in the secondary listening room. This could be improved by providing acoustical treatment inside the closet, and by replacing the bi-fold doors with solid sealing doors. In addition, the dimensions of the secondary room are far from ideal for a listening space, the ratio of width to length being below desirable ranges.

The main listening room was examined in more detail. Aircraft over-flights, associated with BWI Airport are the most significant noise source in the room and raised sound levels in the room by 5 decibels from the background sound levels documented here. I noted that the walls extend to the deck and provide a fair amount of isolation from outside noise. The wall is not sealed where it meets the corrugated deck, and could provide a flanking path for noise in the adjoining lab area. Occasional speech could be heard. There is little sound flanking through the ductwork. I could not determine the wall construction during my visit. The weak part of the construction is the door to the room. Although of solid construction, and equipped with gaskets, it is not a door system (the gaskets were not an integral part of the door), and therefore there is flanking through the door. Leaks in the gaskets were noted and flanking through the door frame was noted. Installation of a rated acoustic door system and a solid threshold would improve the isolation. In addition, there is an unsealed door

between the control room and the listening room which can provide an additional flanking path between the spaces, especially for equipment noise.

Finally, the curtains separating the main area of the listening room from the windows/drum area are not ideal acoustically and were not fully operational (could not close). Either these should be replaced with a folding or sliding partition, acoustically treated on both sides, or optionally, they can be replaced with a more acoustically effective curtain. A theater curtain of velvet, of double width to allow folding can be used, and the existing curtain moved to the window wall itself to provide a less reflective surface in the room thus formed by the new curtain. These curtains should be closed during any testing.

I hope that these results and comments are sufficient for your current requirements.

If you require, I would be pleased to provide an estimate of the time required for any additional engineering analysis (e.g. evaluating the measured data with respect to the ITU R-BS 116.1 or other standard), providing specific recommendations or detailed specifications, or attending meetings to discuss the results, as you may request.

Sincerely,

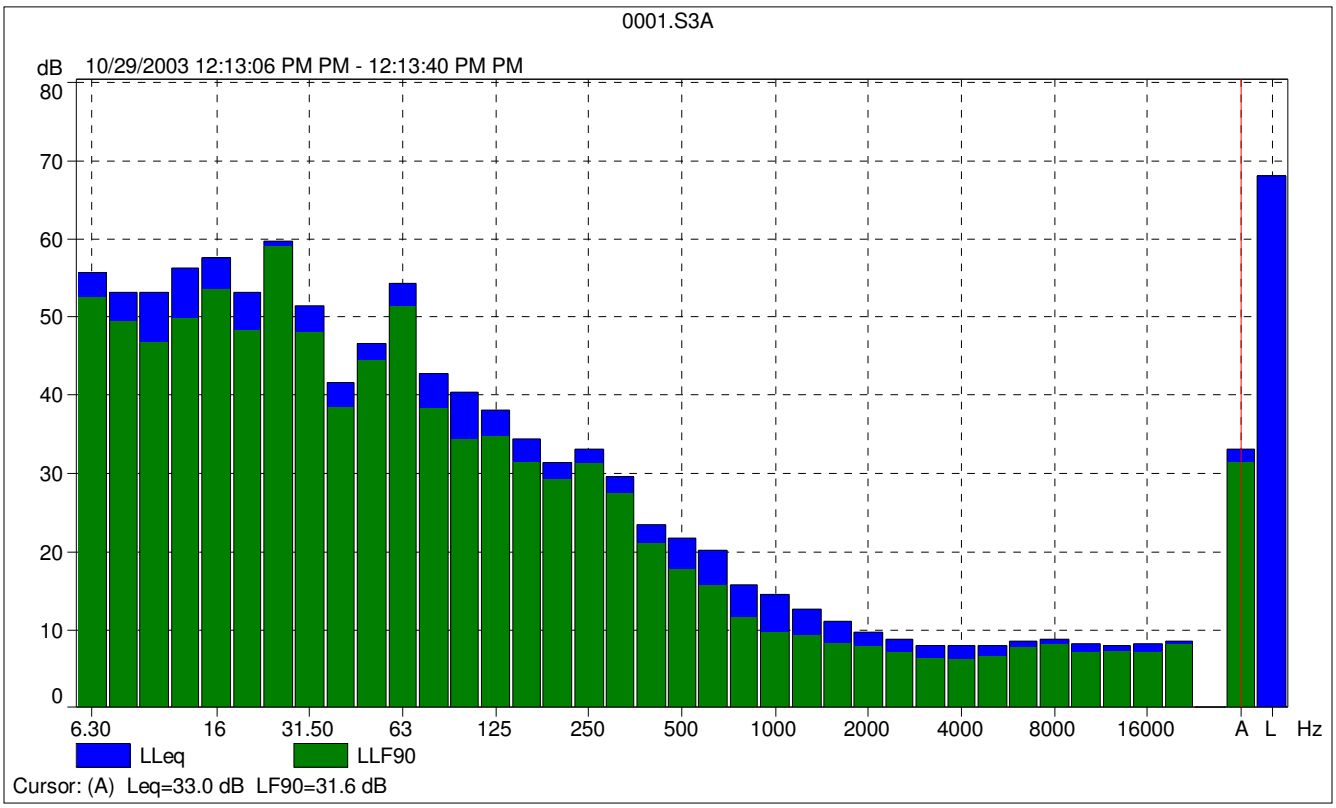
Marty Alexander

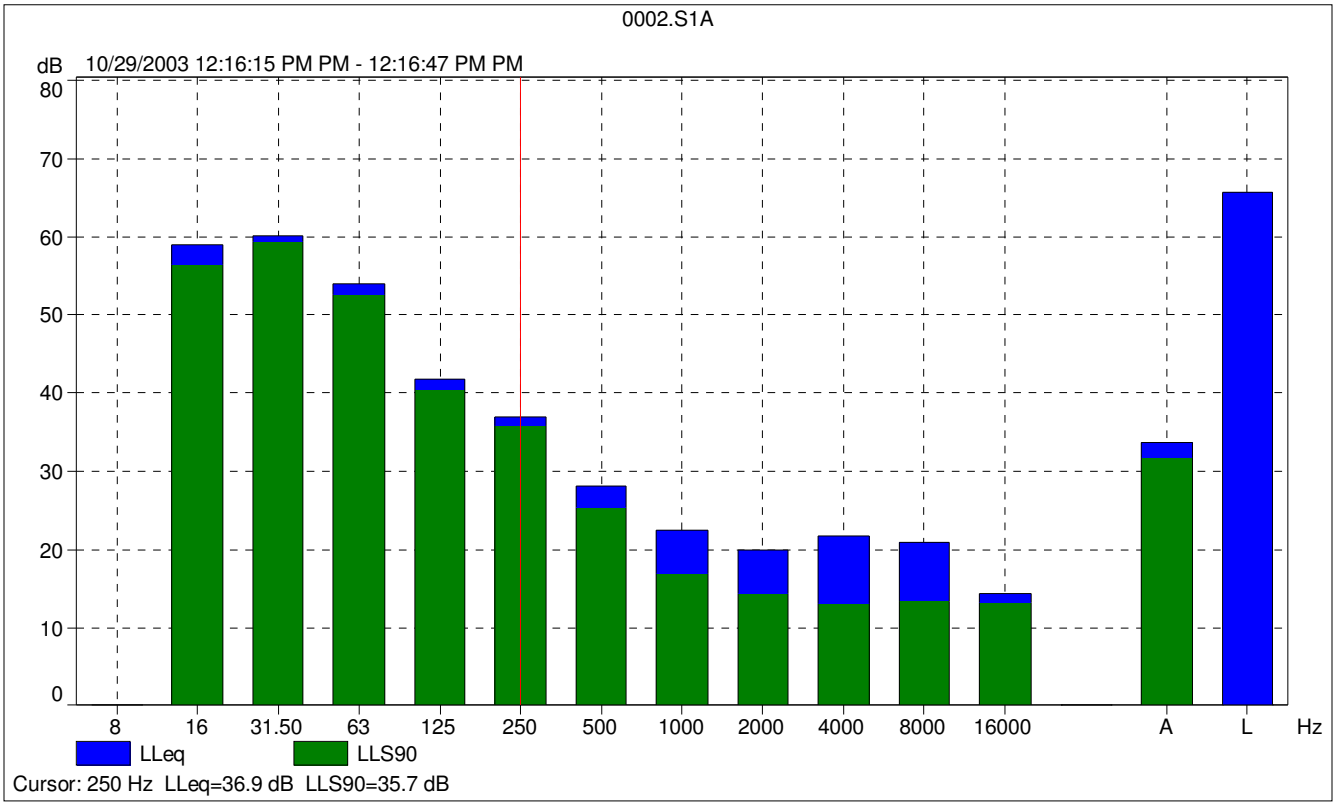
Martin Alexander P.E.

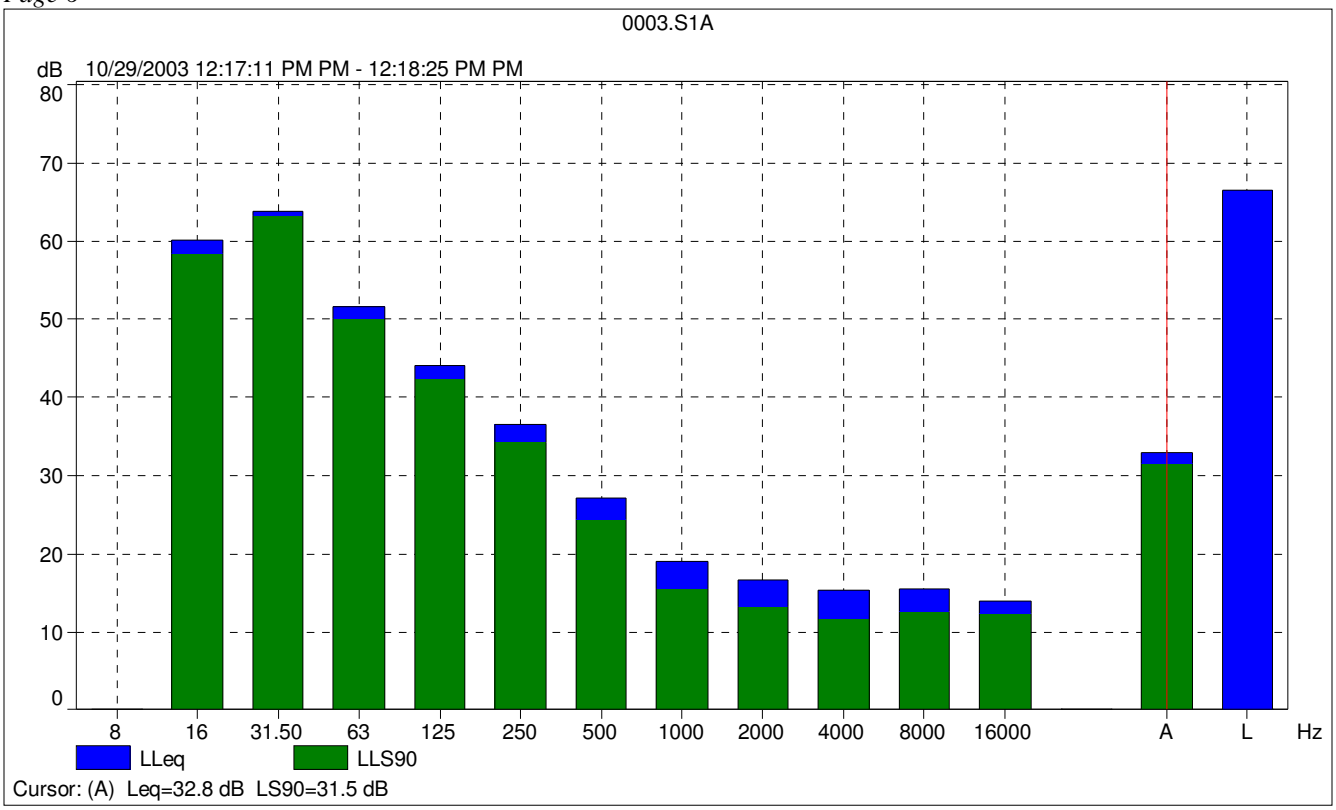
Attachments

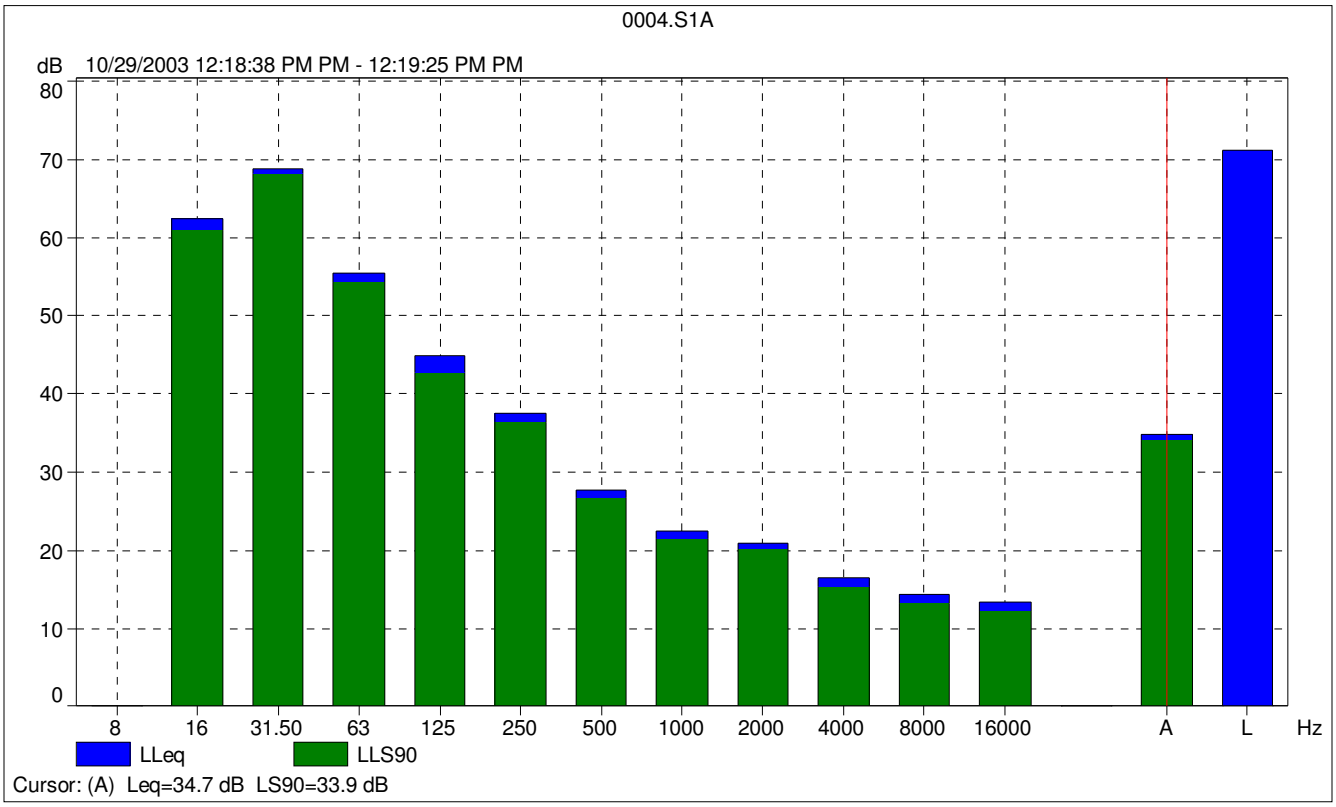
Cc: Ellyn Scheffield

Appendix 1: Summray of Measured Data. Ibiquity, Columbia, MD. Data of 10/30/2003






0003.S1A
dB
10/29/2003 12:17:11 PM PM - 12:18:25 PM PM
80
70
60
50
40
30
20
10
0
8
16
31.50
63
125
250
500
1000
2000
4000
8000
16000
A
L
Hz
LLeq
LLS90
Cursor: (A) Leq=32.8 dB LS90=31.5 dB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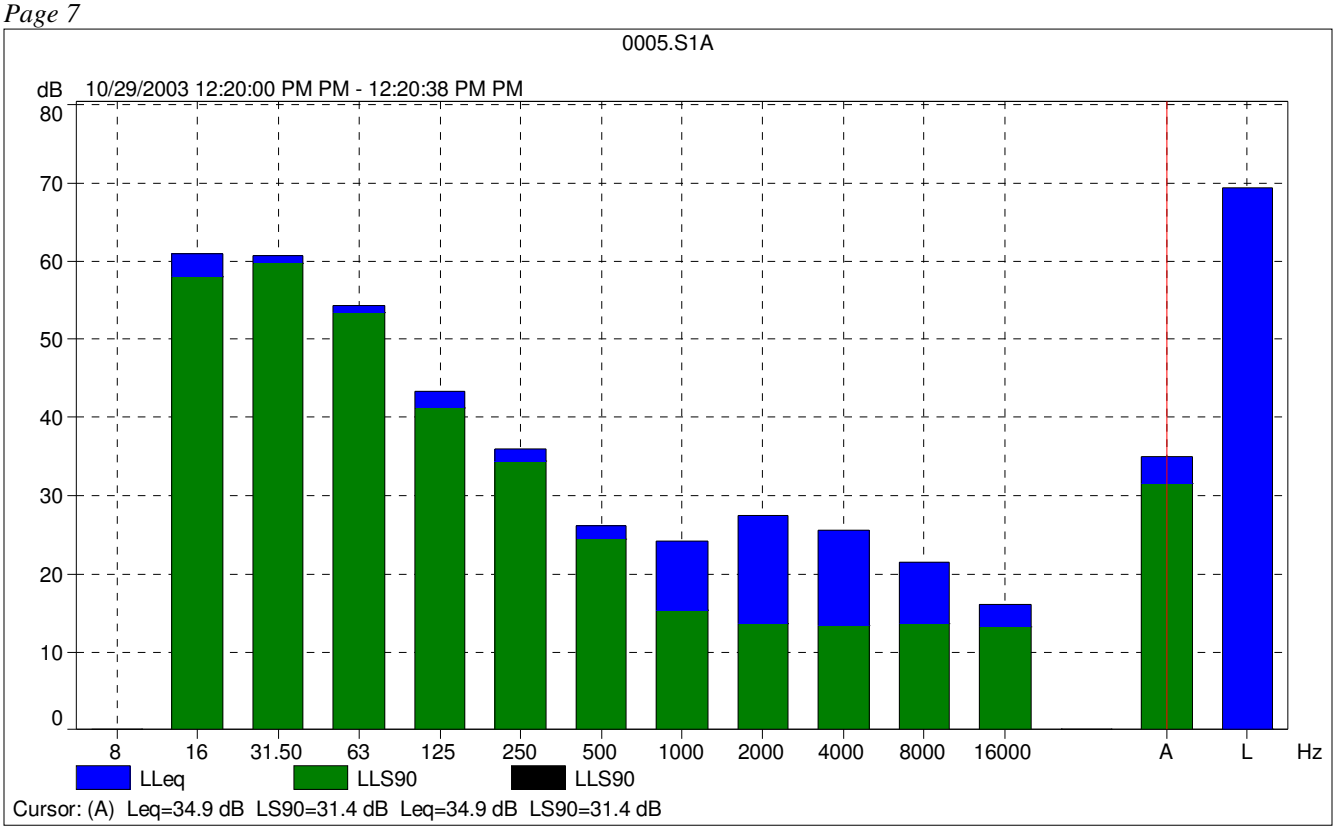
dB
10/29/2003 12:18:38 PM PM - 12:19:25 PM PM
80
70
60
50
40
30
20
10
0
8
16
31.50
63
125
250
500
1000
2000
4000
8000
16000
A
L
Hz
LLeq
LLS90
Cursor: (A) Leq=34.7 dB LS90=33.9 dB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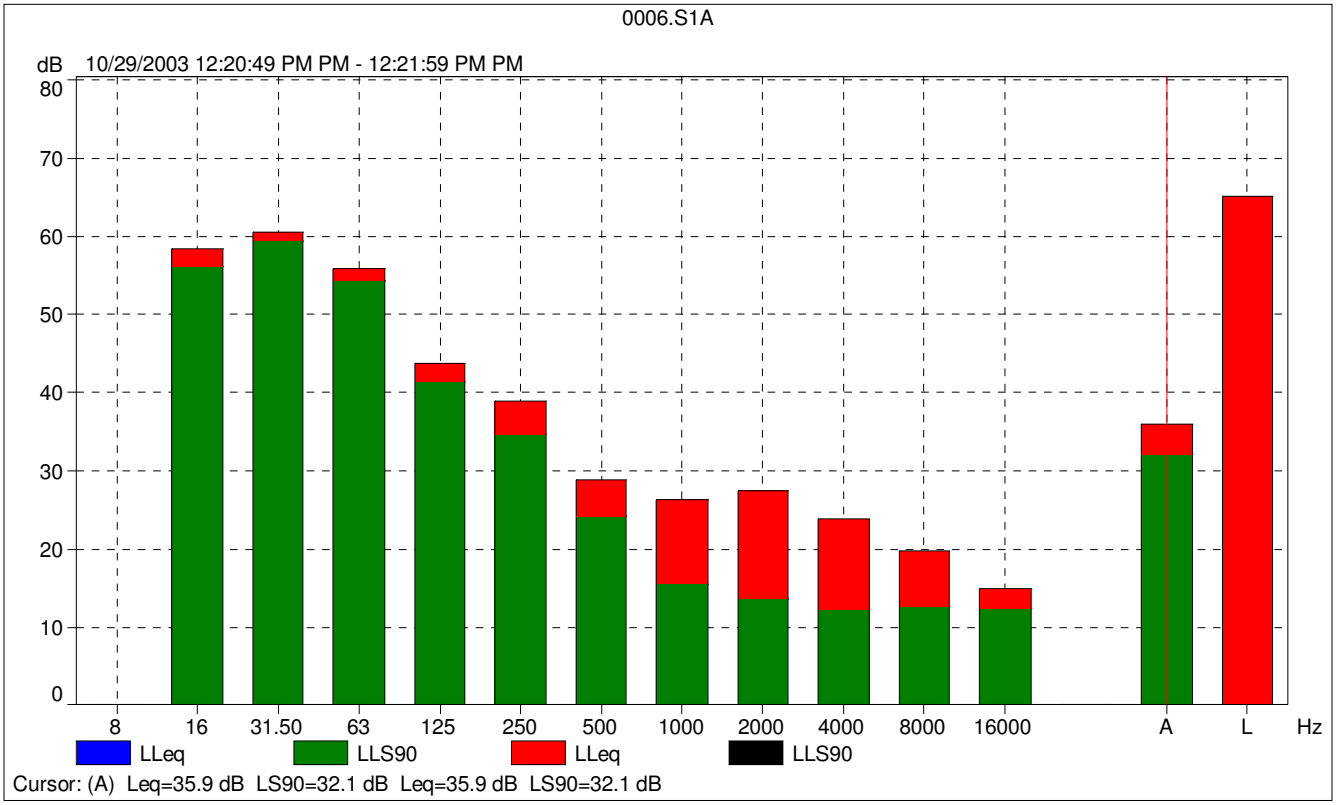
dB 10/29/2003 12:20:00 PM PM - 12:20:38 PM PM
80
70
60
50
40
30
20
10
0
8
16
31.50
63
125
250
500
1000
2000
4000
8000
16000
A
L
Hz
LLeq
LLS90
LLS90
Cursor: (A) Leq=34.9 dB LS90=31.4 dB Leq=34.9 dB LS90=31.4 dB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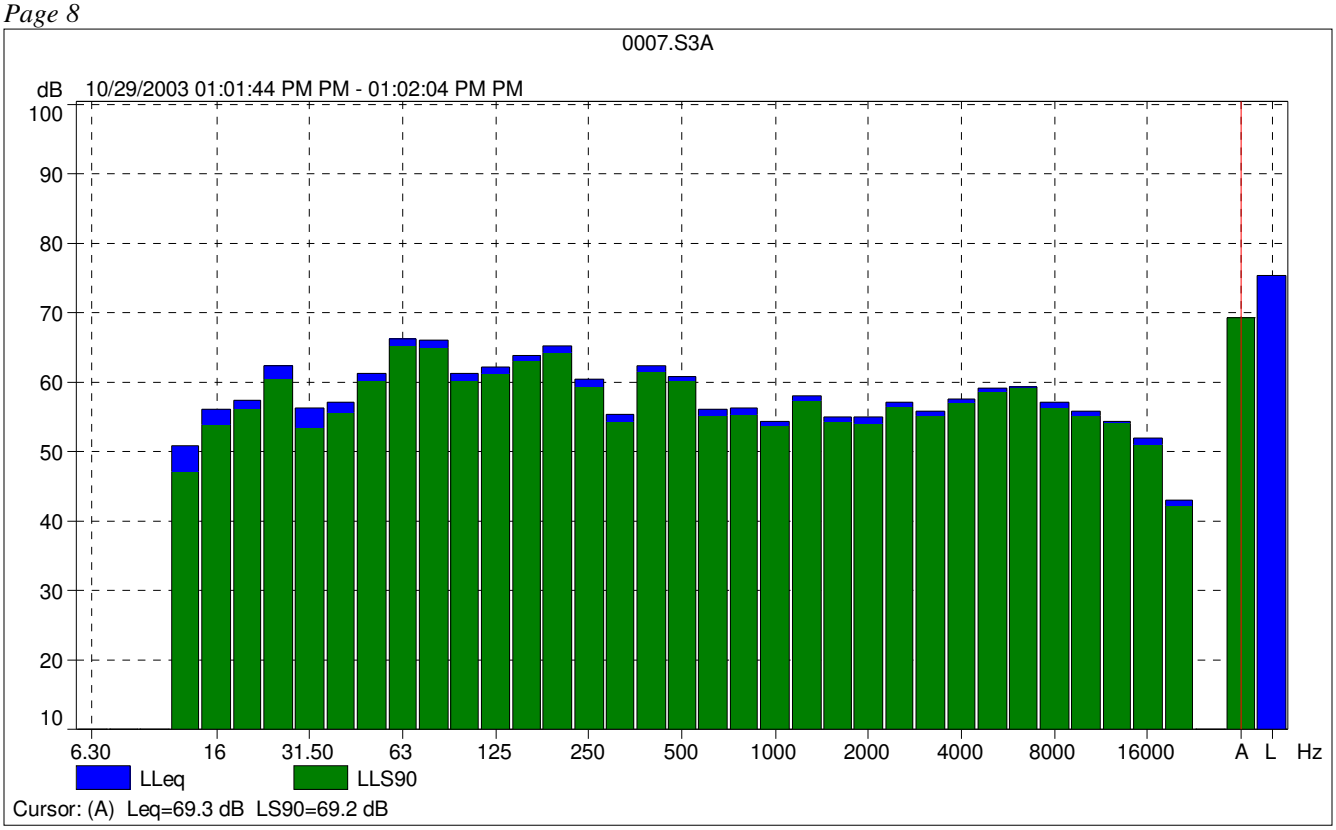
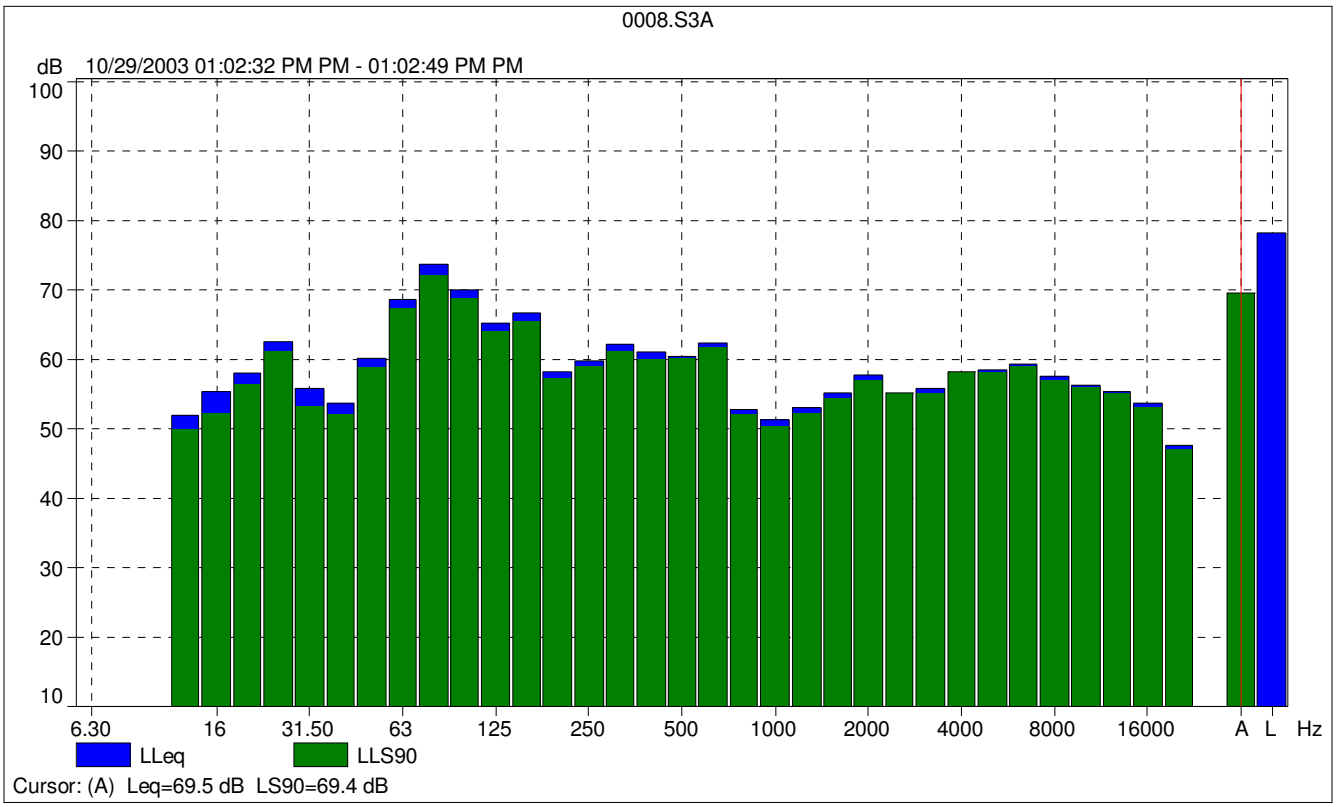
dB 10/29/2003 12:20:49 PM PM - 12:21:59 PM PM
80
70
60
50
40
30
20
10
0
8
16
31.50
63
125
250
500
1000
2000
4000
8000
16000
A
L
Hz
LLeq
LLS90
LLeq
LLS90
Cursor: (A) Leq=35.9 dB LS90=32.1 dB Leq=35.9 dB LS90=32.1 dB


0007.S3A
dB 10/29/2003 01:01:44 PM PM - 01:02:04 PM PM
100
90
80
70
60
50
40
30
20
10
6.30
16
31.50
63
125
250
500
1000
2000
4000
8000
16000
A L Hz
LLeq
LLS90
Cursor: (A) Leq=69.3 dB LS90=69.2 dB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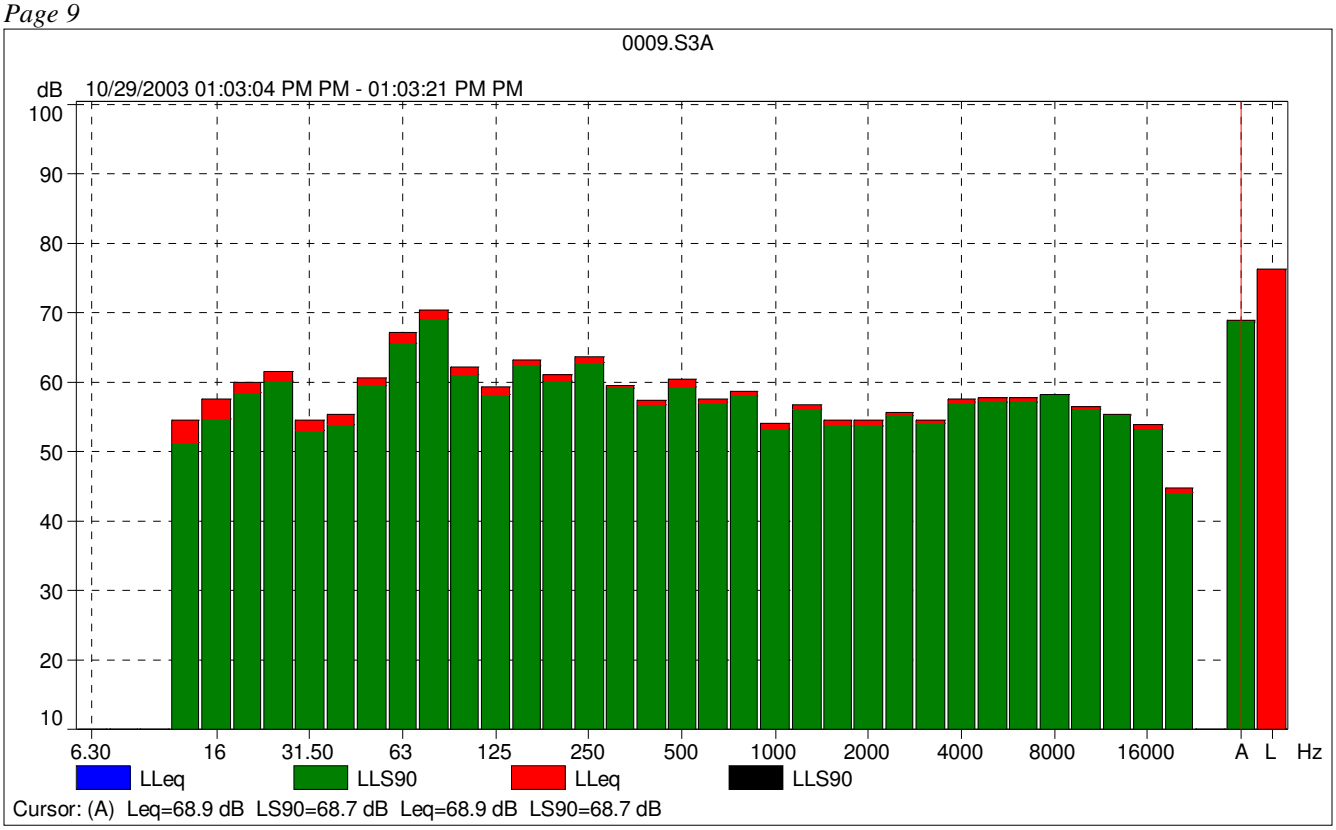
dB 10/29/2003 01:02:32 PM PM - 01:02:49 PM PM
100
90
80
70
60
50
40
30
20
10
6.30
16
31.50
63
125
250
500
1000
2000
4000
8000
16000
A L Hz
LLeq
LLS90
Cursor: (A) Leq=69.5 dB LS90=69.4 dB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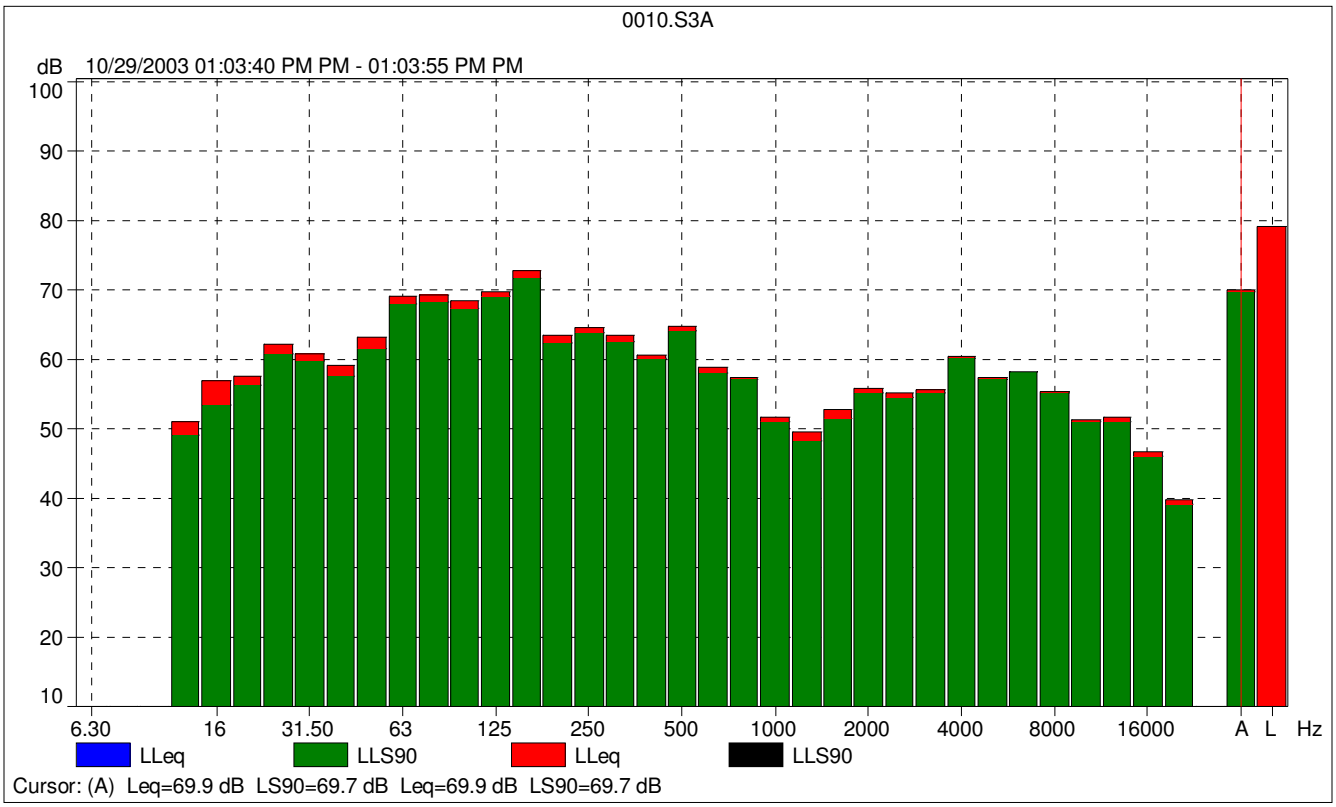
dB 10/29/2003 01:03:04 PM PM - 01:03:21 PM PM
100
90
80
70
60
50
40
30
20
10
6.30
16
31.50
63
125
250
500
1000
2000
4000
8000
16000
A L Hz
LLeq
LLS90
LLeq
LLS90
Cursor: (A) Leq=68.9 dB LS90=68.7 dB Leq=68.9 dB LS90=68.7 dB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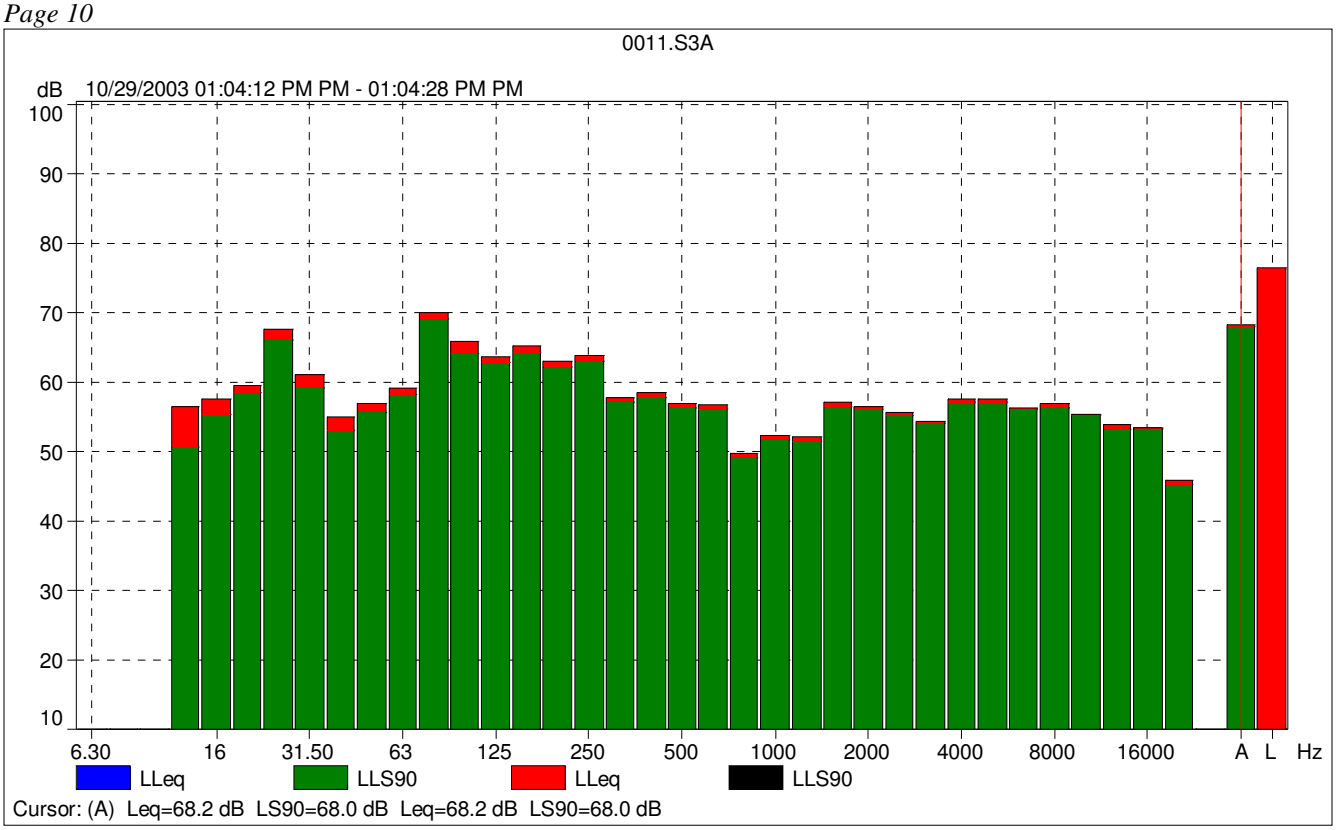
90
80
70
60
50
40
30
20
10
6.30
16
31.50
63
125
250
500
1000
2000
4000
8000
16000
A L Hz
LLeq
LLS90
LLeq
LLS90
Cursor: (A) Leq=69.9 dB LS90=69.7 dB Leq=69.9 dB LS90=69.7 dB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dB
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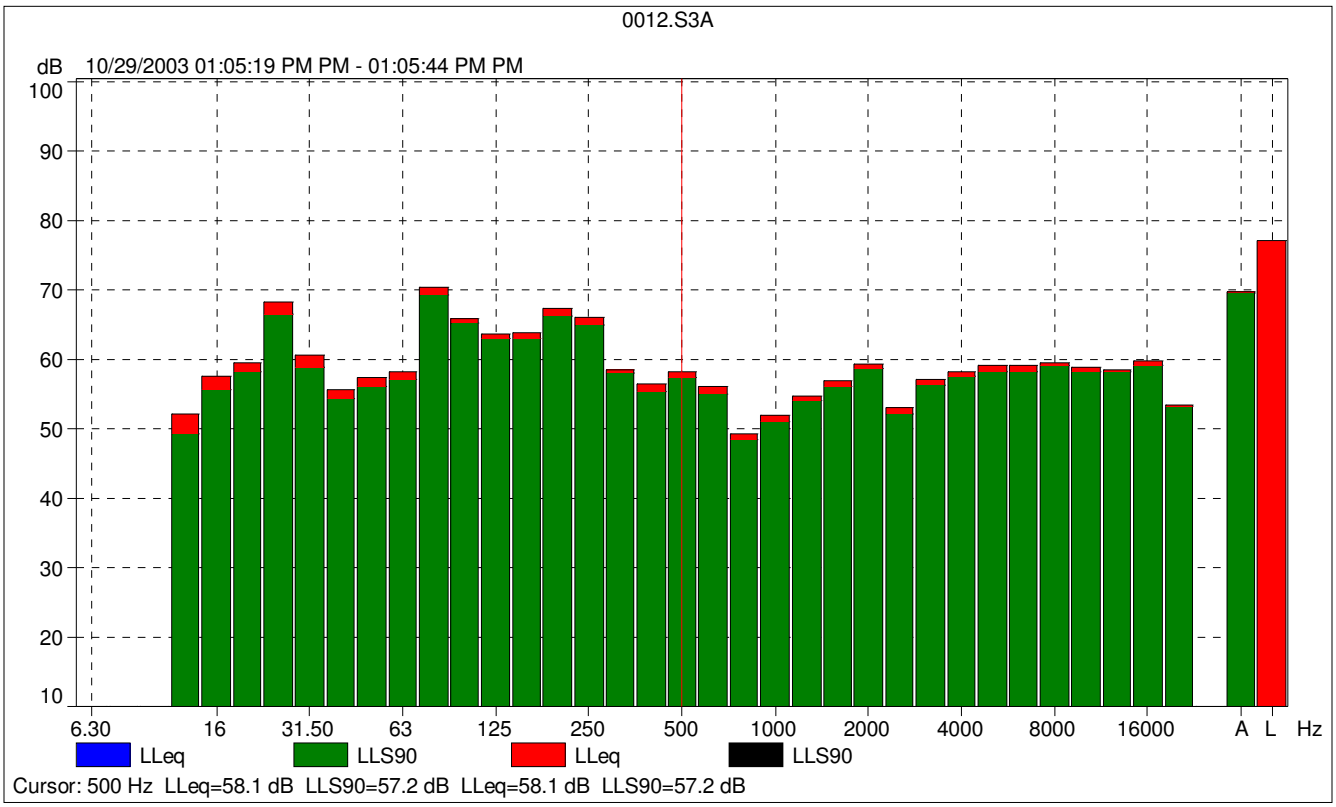
90
80
70
60
50
40
30
20
10
6.30
16
31.50
63
125
250
500
1000
2000
4000
8000
16000
A
L
Hz
LLeq
LLS90
LLeq
LLS90
Cursor: (A) Leq=68.2 dB LS90=68.0 dB Leq=68.2 dB LS90=68.0 dB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dB
10/29/2003 01:05:19 PM PM - 01:05:44 PM PM
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90
80
70
60
50
40
30
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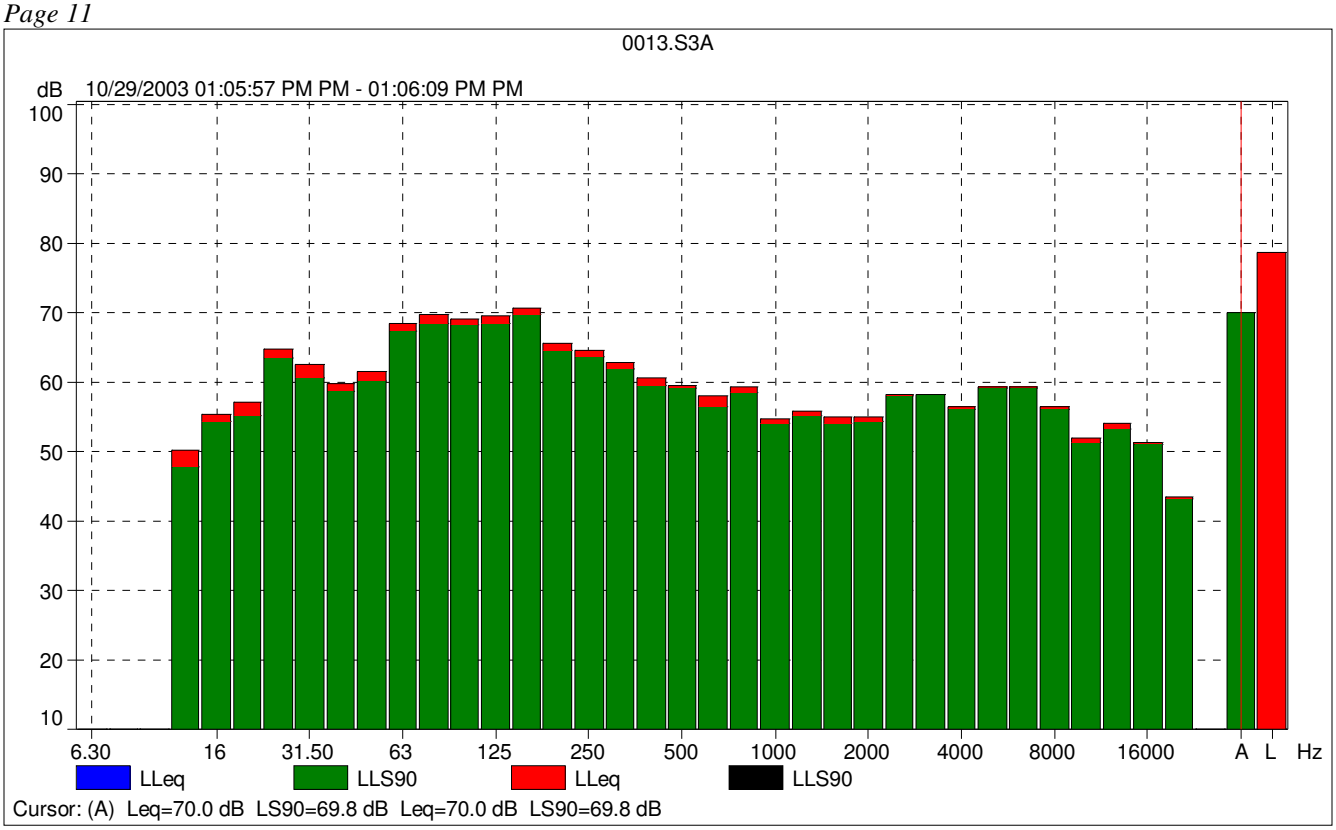
6.30
16
31.50
63
125
250
500
1000
2000
4000
8000
16000
A
L
Hz
LLeq
LLS90
LLeq
LLS90
Cursor: 500 Hz LLeq=58.1 dB LLS90=57.2 dB LLeq=58.1 dB LLS90=57.2 dB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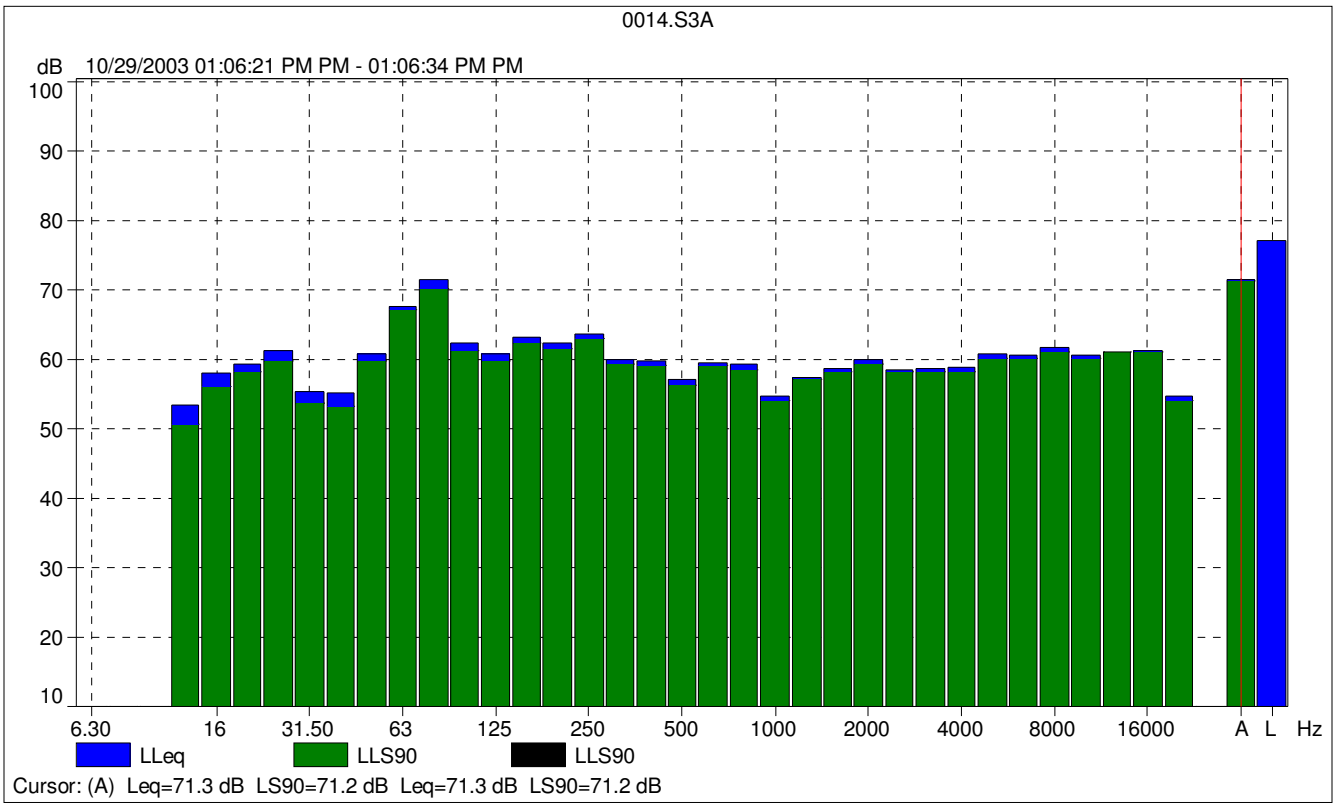
90
80
70
60
50
40
30
20
10
6.30
16
31.50
63
125
250
500
1000
2000
4000
8000
16000
A L Hz
LLeq
LLS90
LLeq
LLS90
Cursor: (A) Leq=70.0 dB LS90=69.8 dB Leq=70.0 dB LS90=69.8 dB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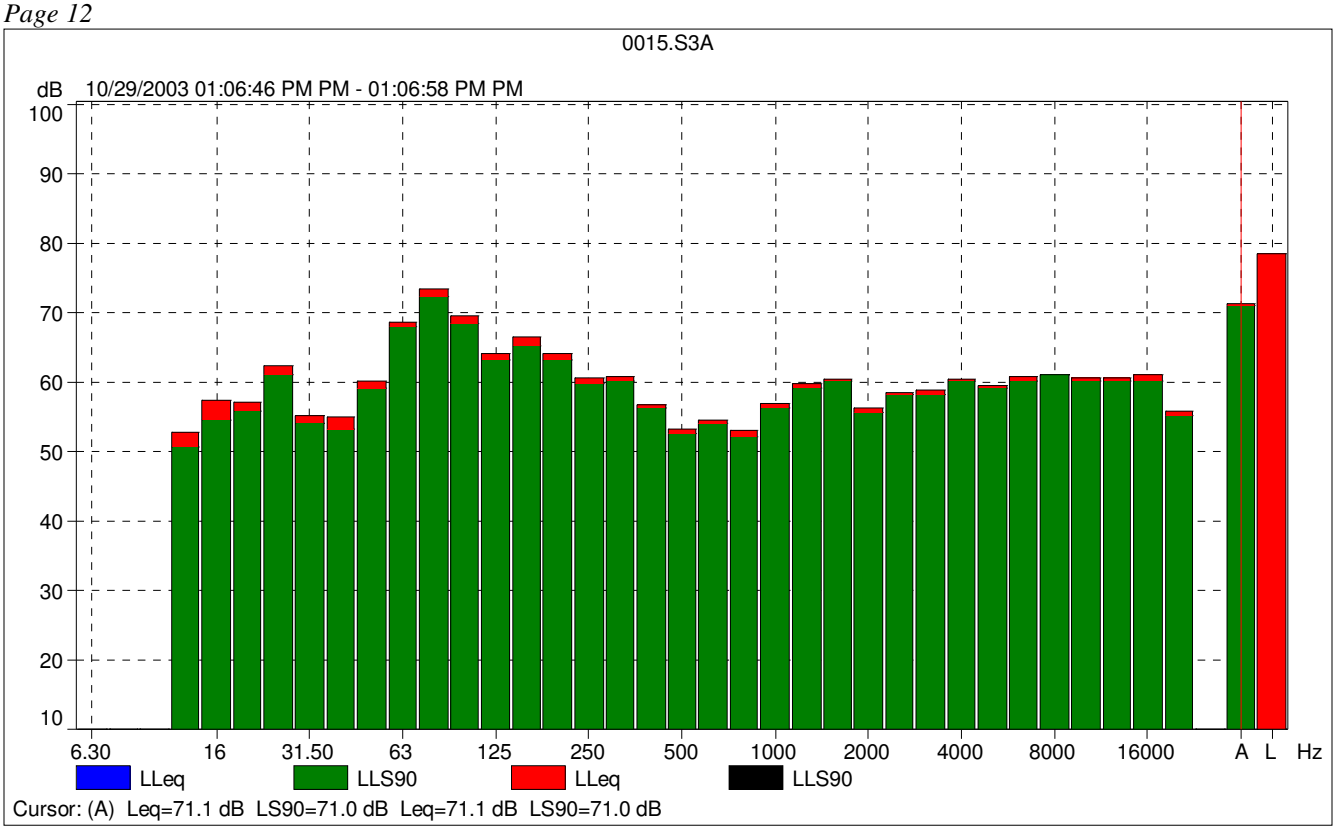
90
80
70
60
50
40
30
20
10
6.30
16
31.50
63
125
250
500
1000
2000
4000
8000
16000
A L Hz
LLeq
LLS90
LLS90
Cursor: (A) Leq=71.3 dB LS90=71.2 dB Leq=71.3 dB LS90=71.2 dB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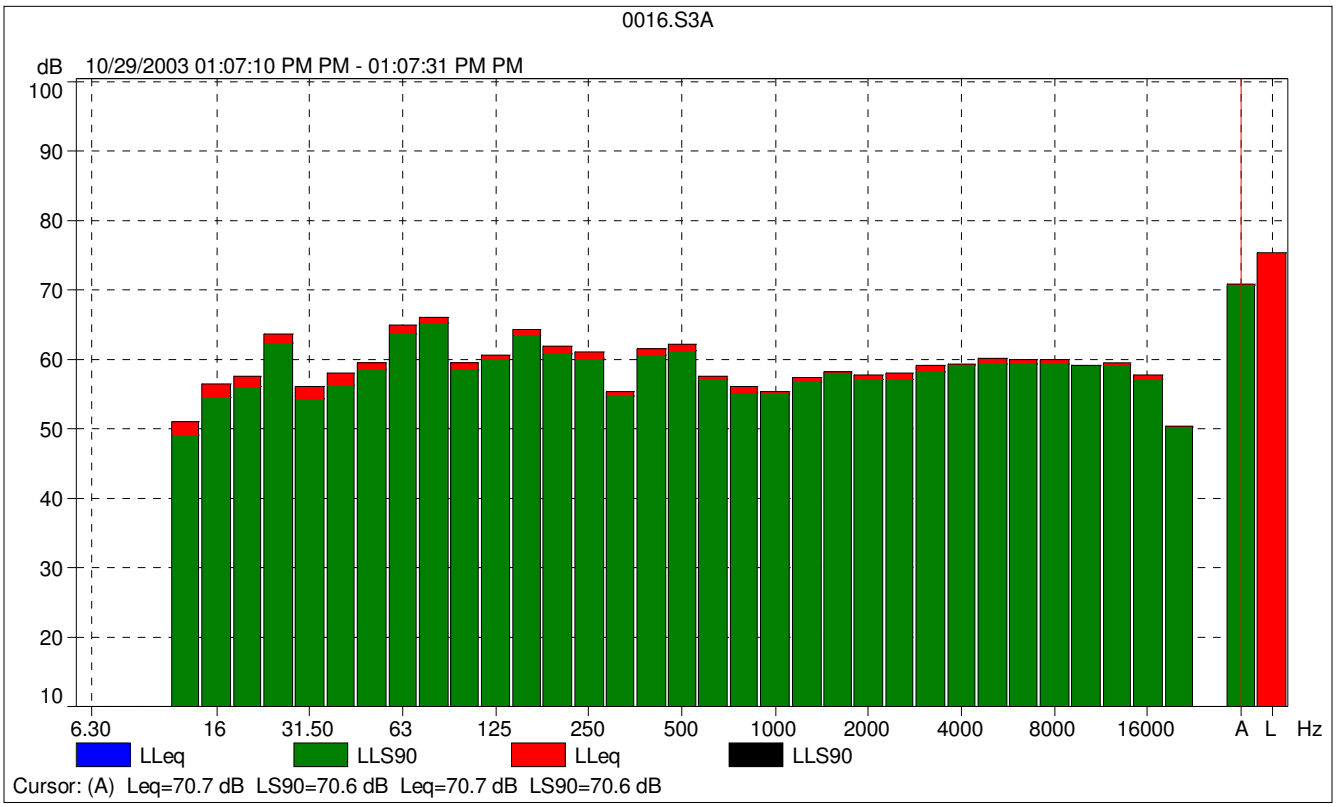
90
80
70
60
50
40
30
20
10
6.30
16
31.50
63
125
250
500
1000
2000
4000
8000
16000
A
L
Hz
LLeq
LLS90
LLeq
LLS90
Cursor: (A) Leq=71.1 dB LS90=71.0 dB Leq=71.1 dB LS90=71.0 dB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dB
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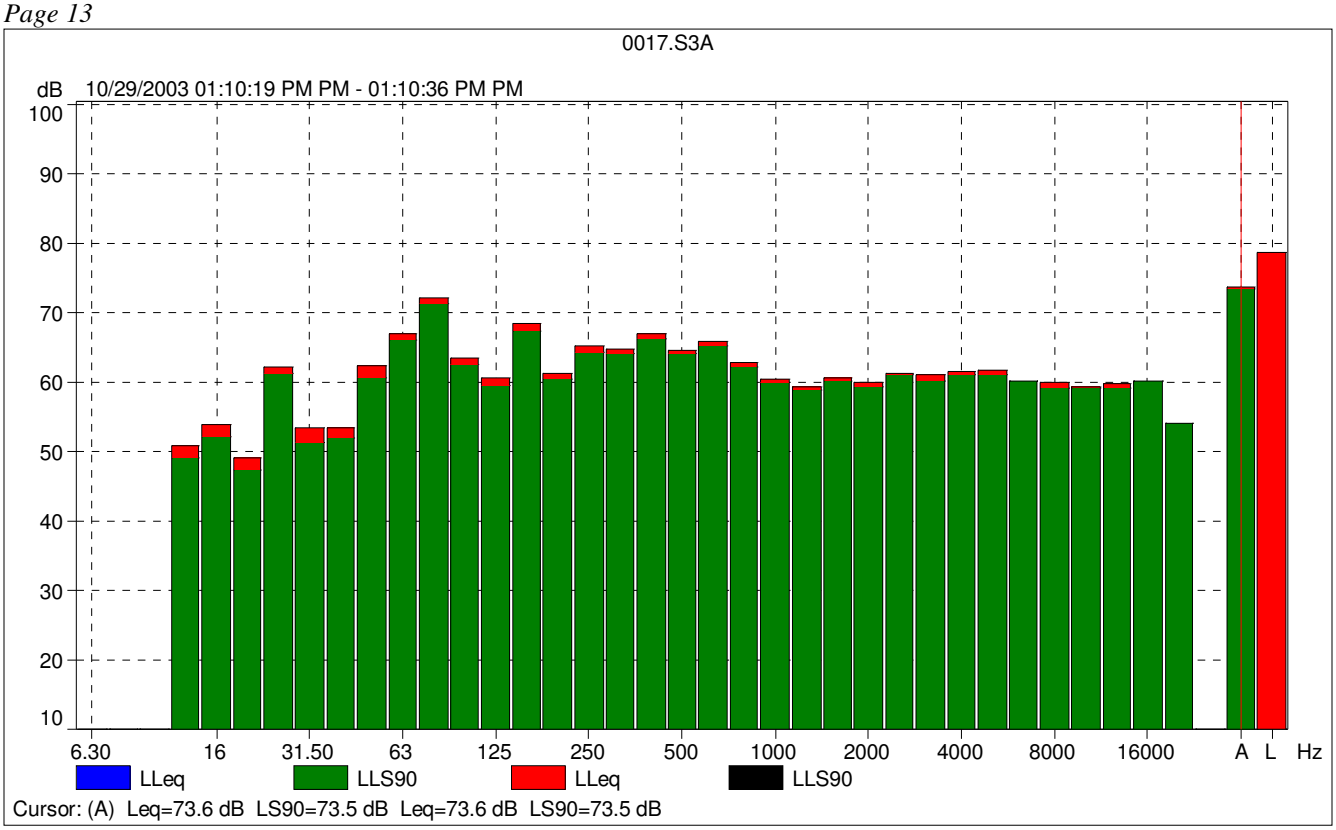
90
80
70
60
50
40
30
20
10
6.30
16
31.50
63
125
250
500
1000
2000
4000
8000
16000
A
L
Hz
LLeq
LLS90
LLeq
LLS90
Cursor: (A) Leq=70.7 dB LS90=70.6 dB Leq=70.7 dB LS90=70.6 dB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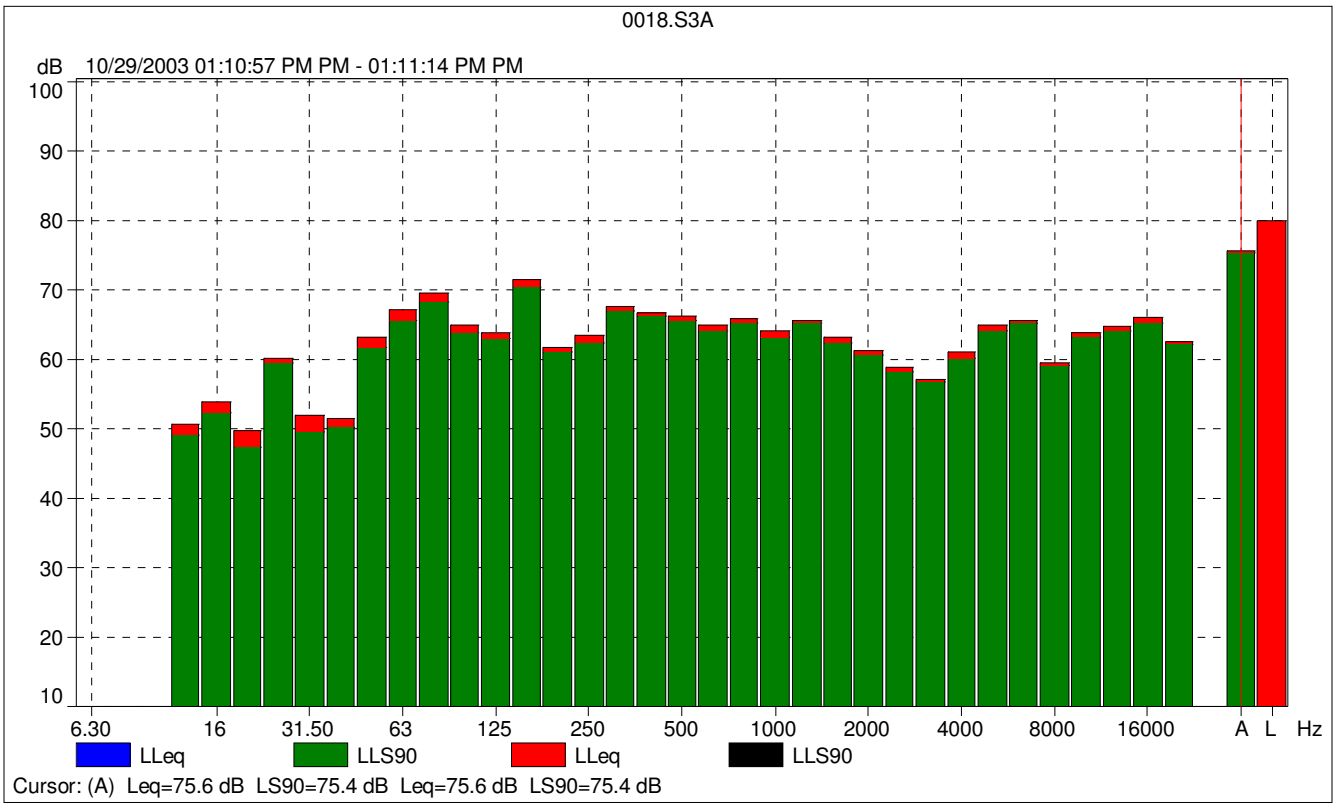
90
80
70
60
50
40
30
20
10
6.30
16
31.50
63
125
250
500
1000
2000
4000
8000
16000
A
L
Hz
LLeq
LLS90
LLeq
LLS90
Cursor: (A) Leq=73.6 dB LS90=73.5 dB Leq=73.6 dB LS90=73.5 dB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dB
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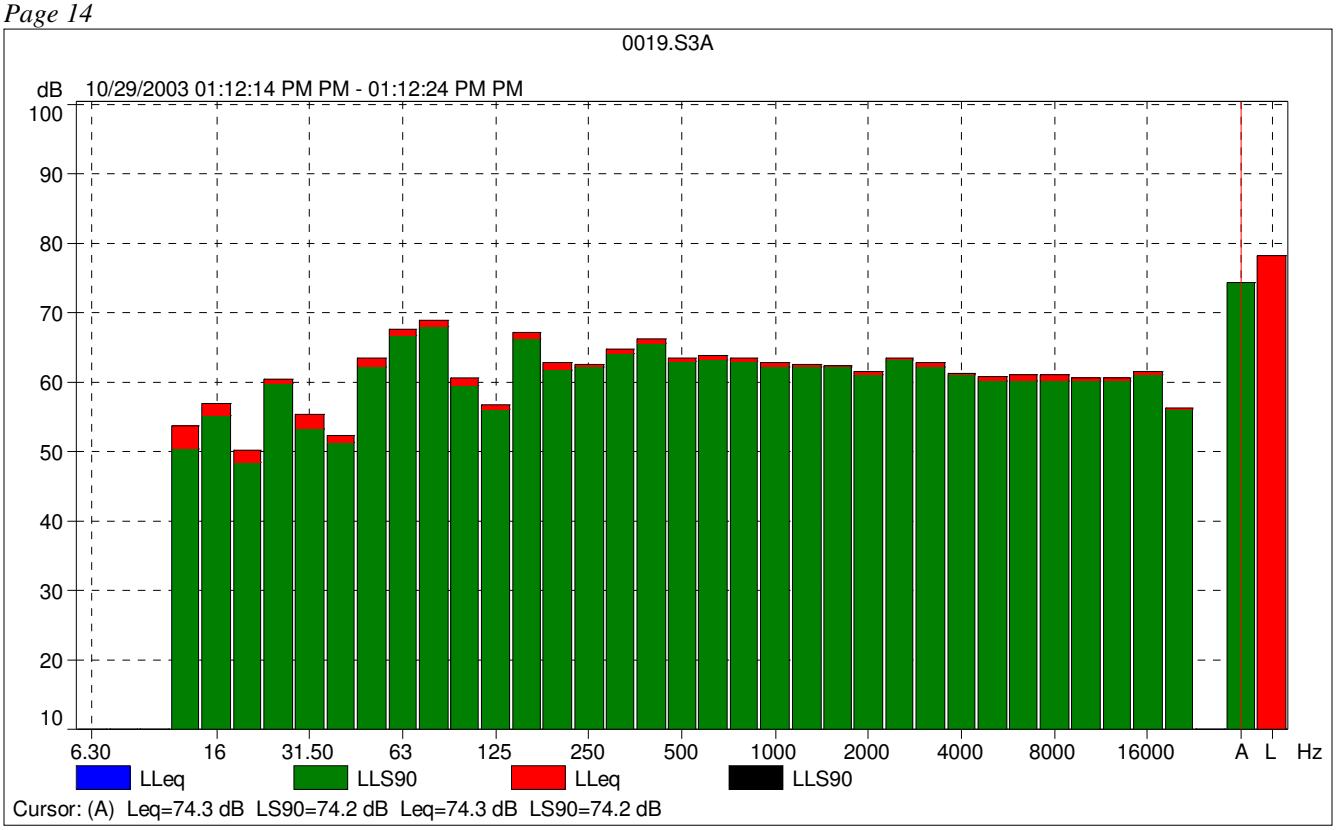
90
80
70
60
50
40
30
20
10
6.30
16
31.50
63
125
250
500
1000
2000
4000
8000
16000
A
L
Hz
LLeq
LLS90
LLeq
LLS90
Cursor: (A) Leq=75.6 dB LS90=75.4 dB Leq=75.6 dB LS90=75.4 dB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dB
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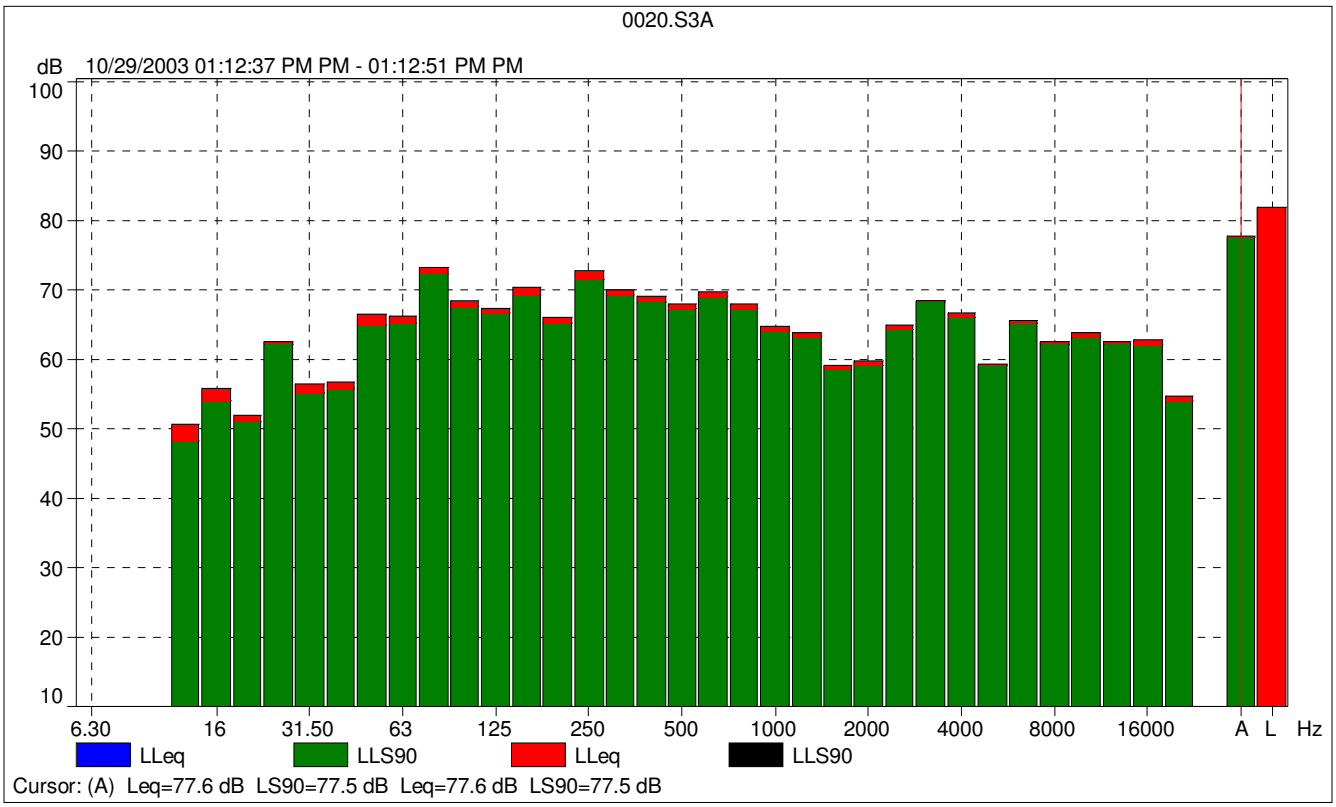
100
90
80
70
60
50
40
30
20
10
6.30
16
31.50
63
125
250
500
1000
2000
4000
8000
16000
A
L
Hz
LLeq
LLS90
LLeq
LLS90
Cursor: (A) Leq=74.3 dB LS90=74.2 dB Leq=74.3 dB LS90=74.2 dB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dB
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90
80
70
60
50
40
30
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10
6.30
16
31.50
63
125
250
500
1000
2000
4000
8000
16000
A
L
Hz
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LLS90
LLeq
LLS90
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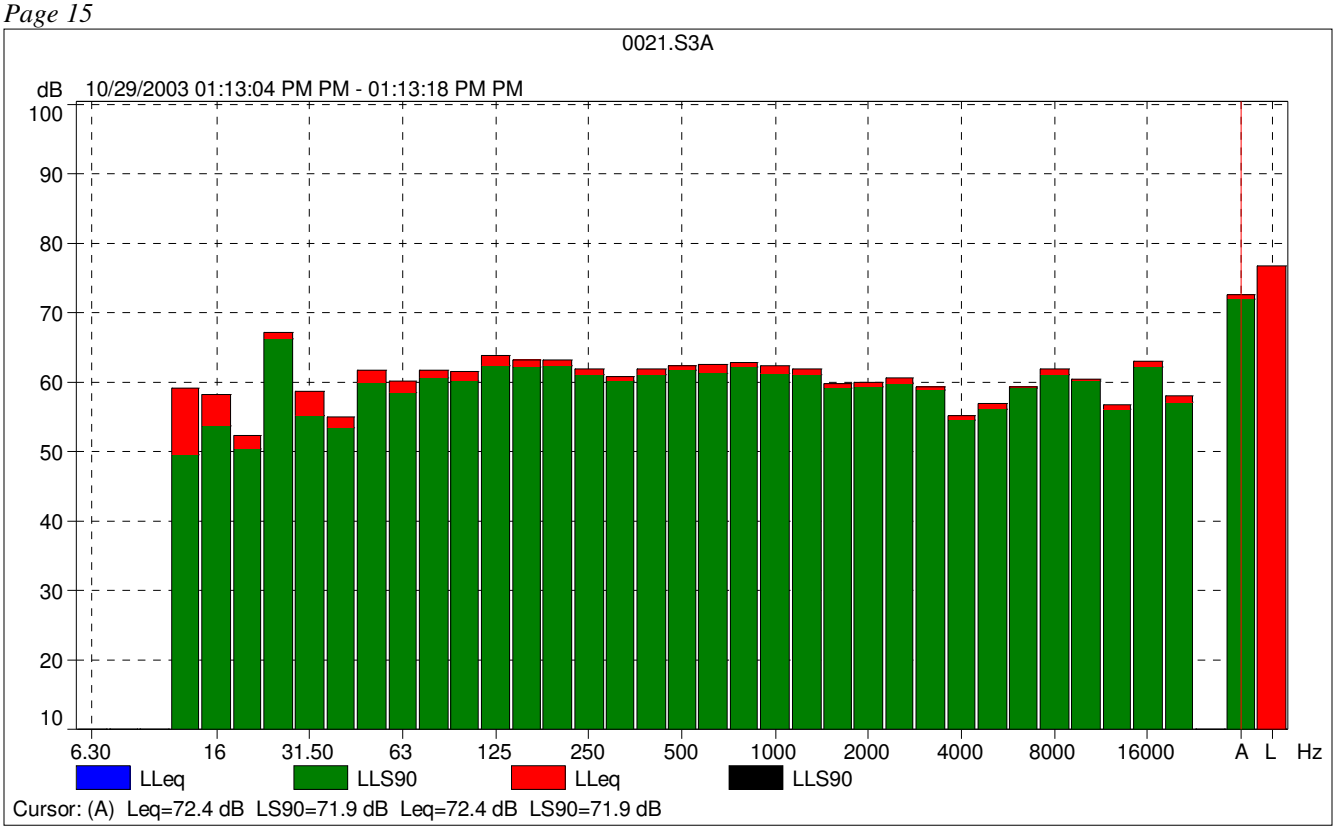
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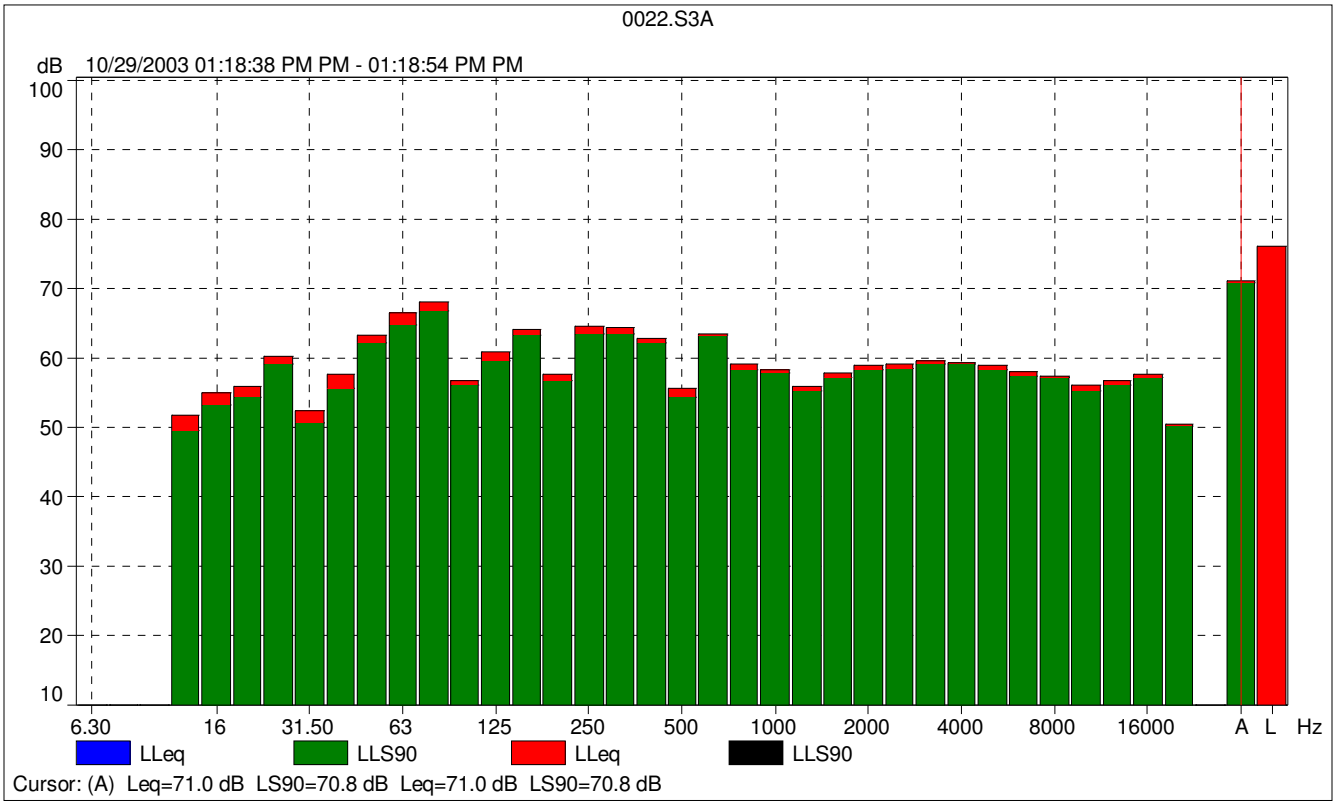
dB 10/29/2003 01:13:04 PM PM - 01:13:18 PM PM
100
90
80
70
60
50
40
30
20
10
6.30
16
31.50
63
125
250
500
1000
2000
4000
8000
16000
A L Hz
LLeq
LLS90
LLeq
LLS90
Cursor: (A) Leq=72.4 dB LS90=71.9 dB Leq=72.4 dB LS90=71.9 dB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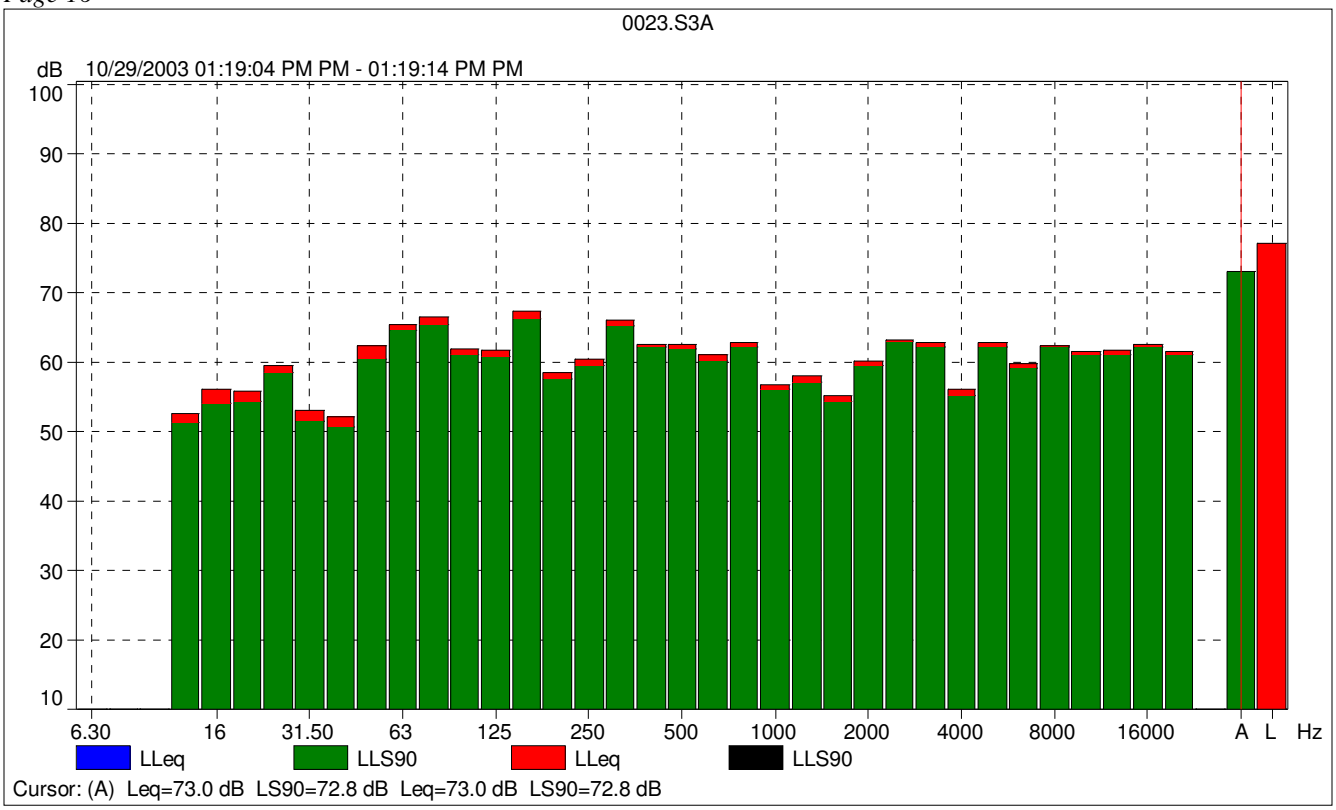
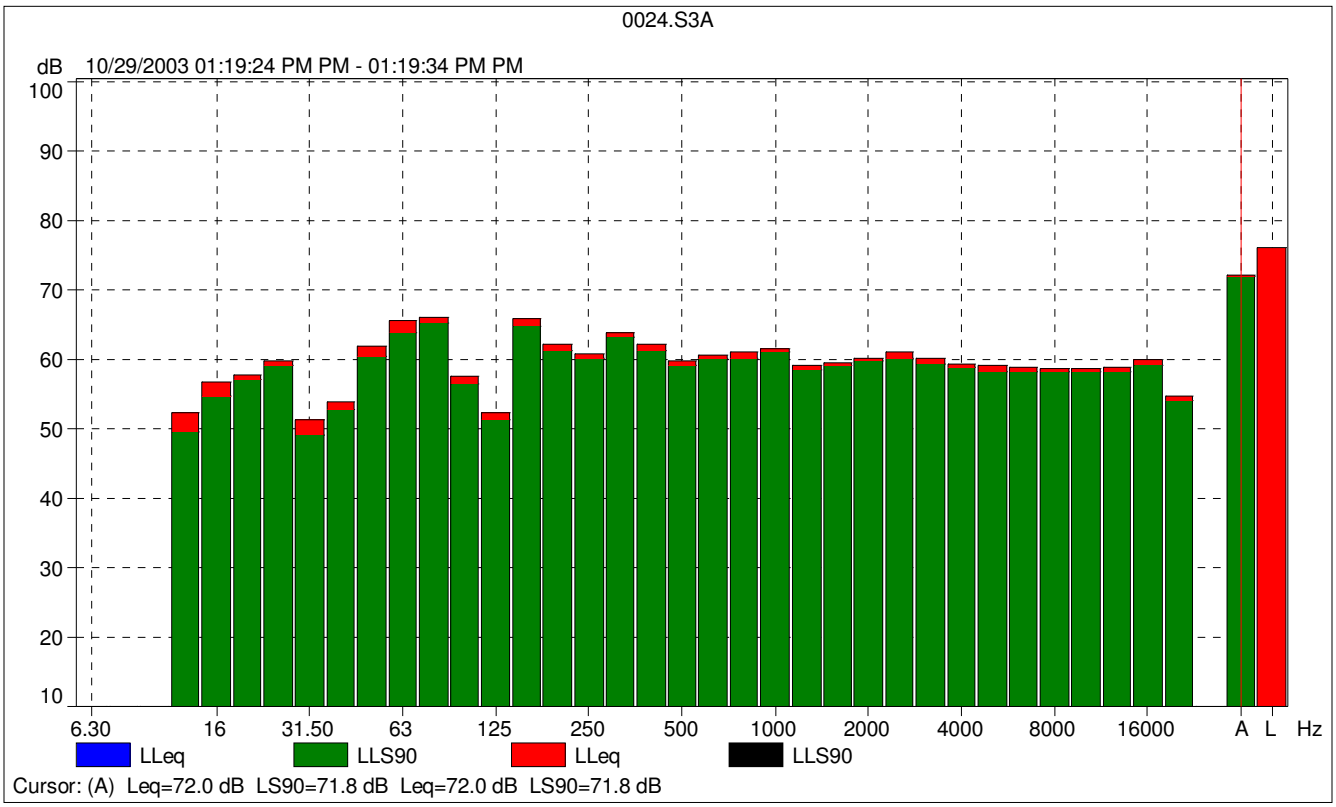
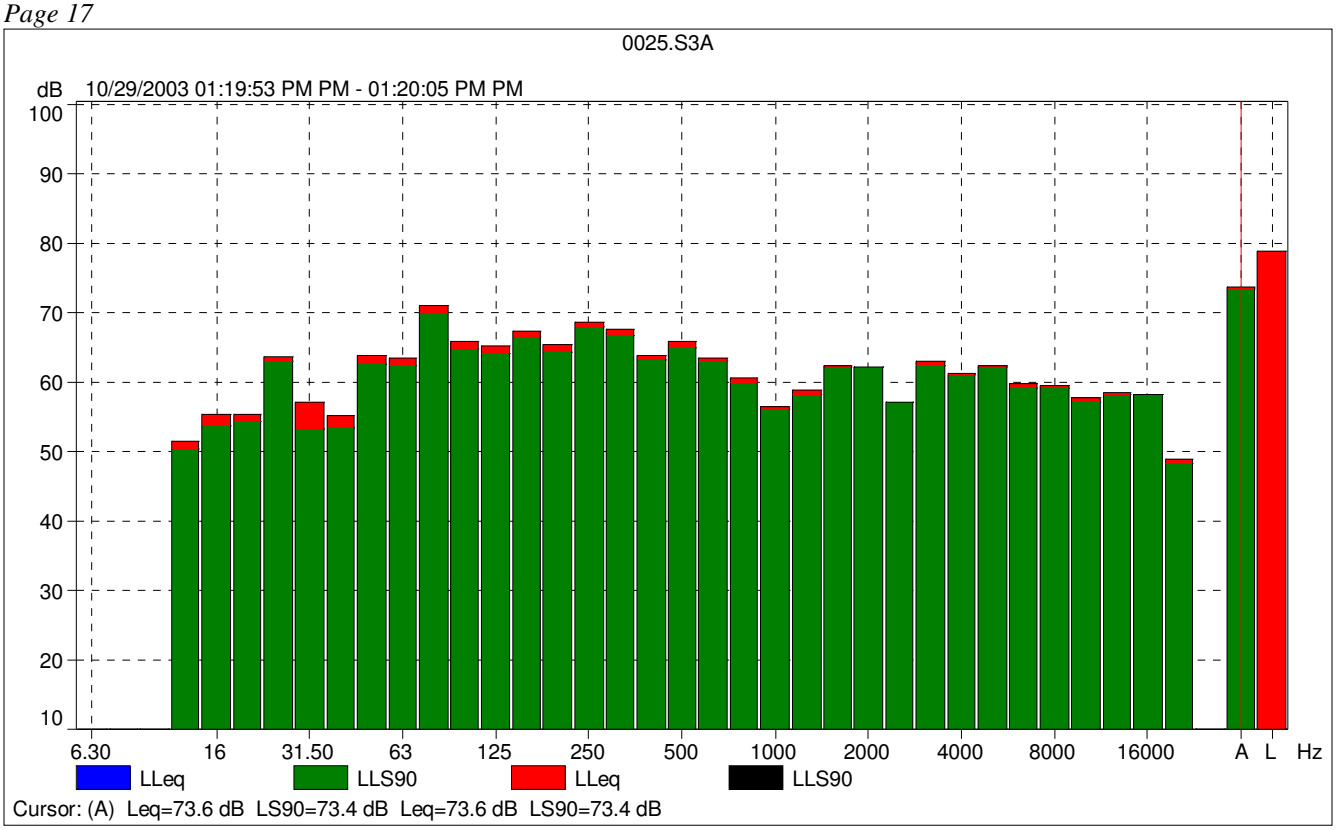
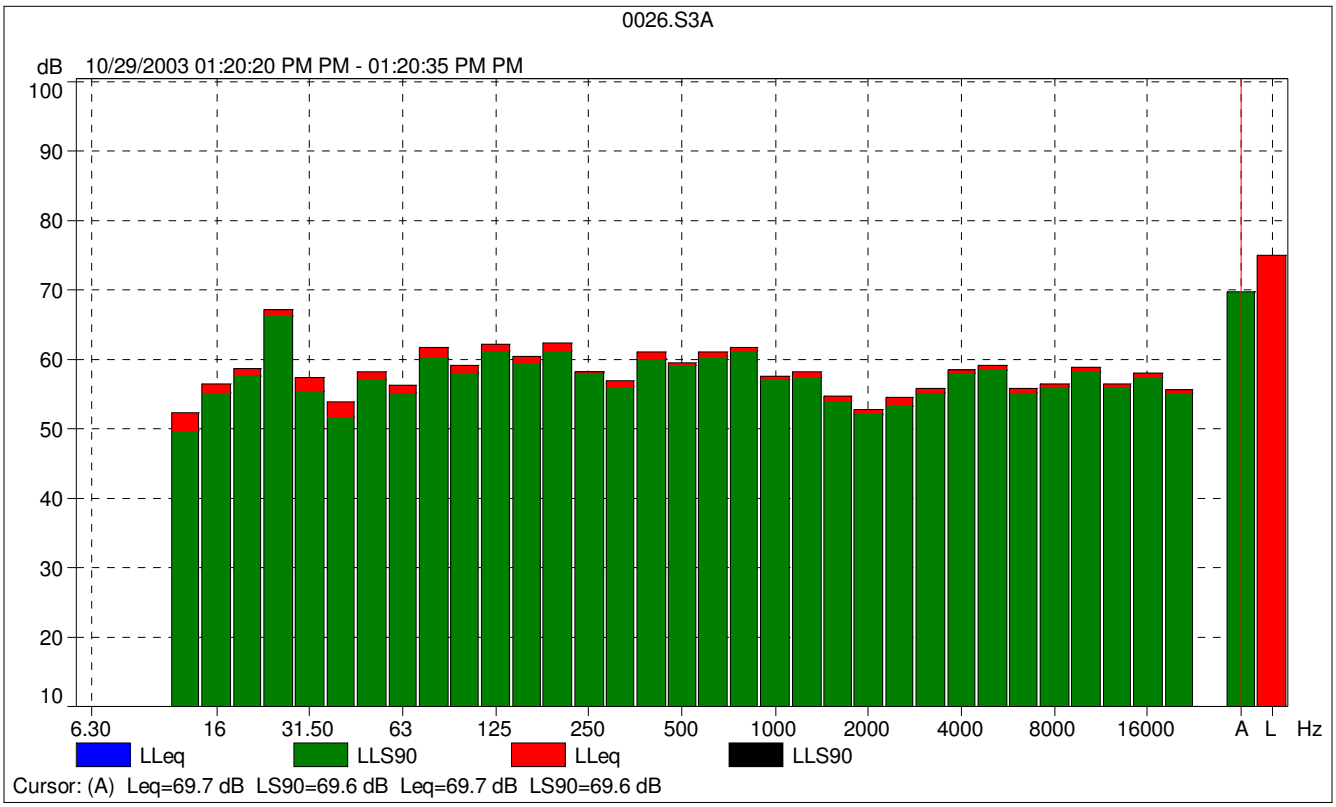
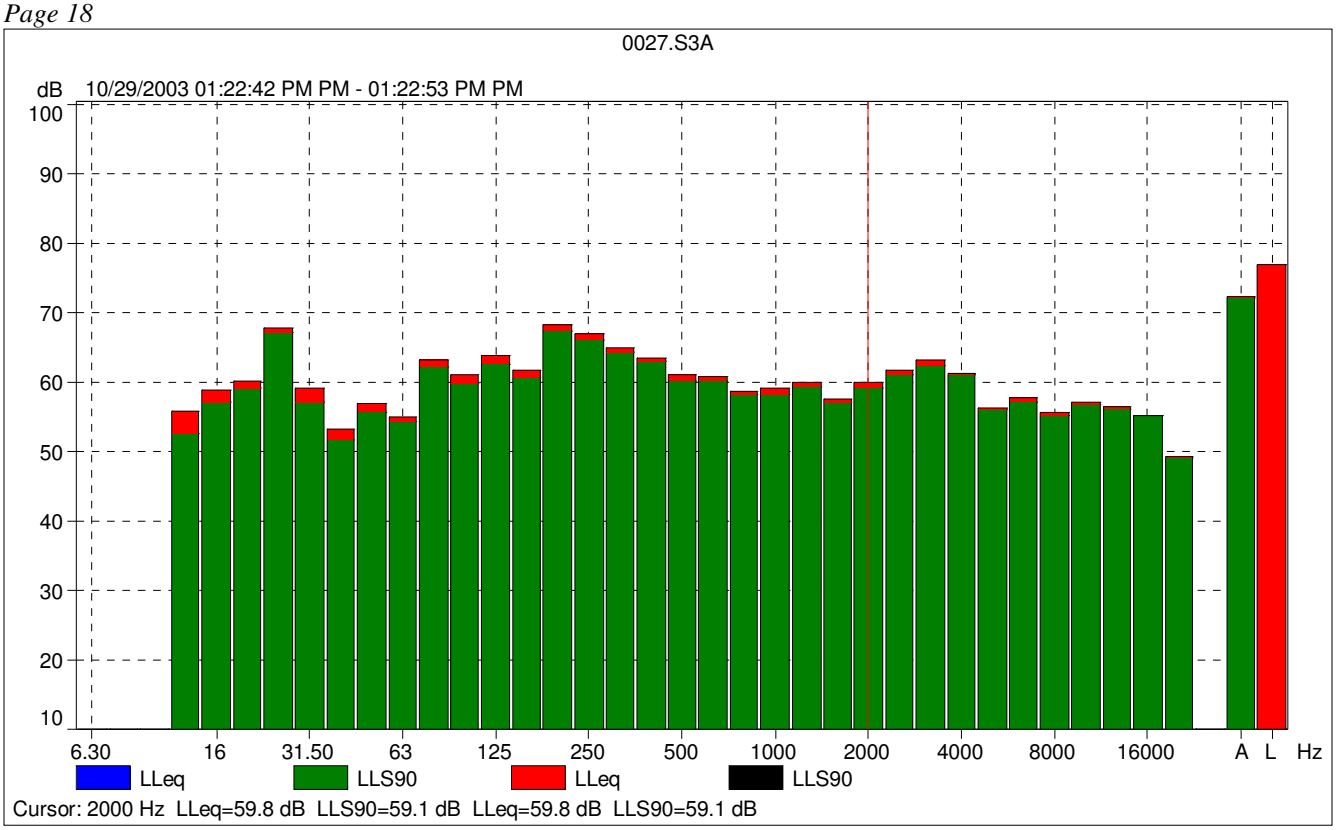
dB 10/29/2003 01:18:38 PM PM - 01:18:54 PM PM
100
90
80
70
60
50
40
30
20
10
6.30
16
31.50
63
125
250
500
1000
2000
4000
8000
16000
A L Hz
LLeq
LLS90
LLeq
LLS90
Cursor: (A) Leq=71.0 dB LS90=70.8 dB Leq=71.0 dB LS90=70.8 dB

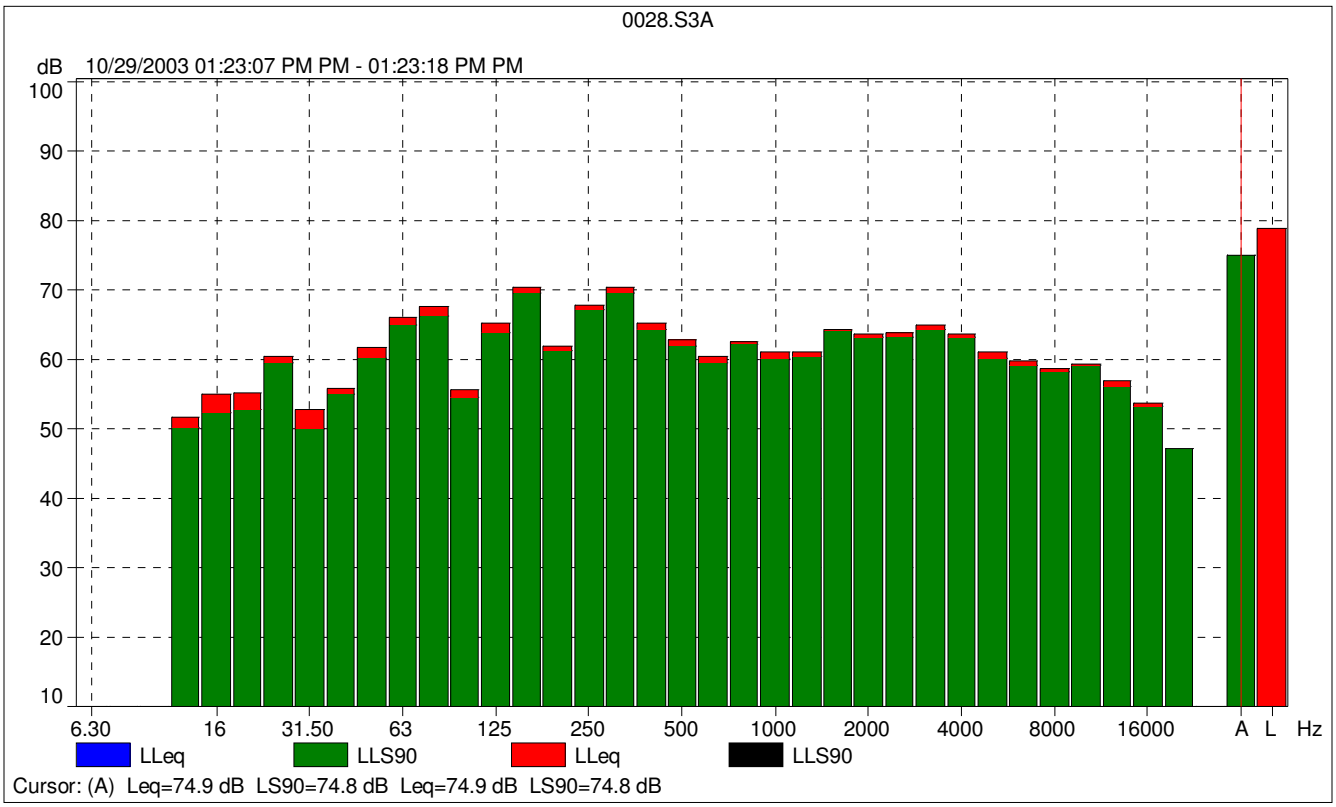

0023.S3A
dB 10/29/2003 01:19:04 PM PM - 01:19:14 PM PM
100
90
80
70
60
50
40
30
20
10
6.30
16
31.50
63
125
250
500
1000
2000
4000
8000
16000
A L Hz
LLeq
LLS90
LLeq
LLS90
Cursor: (A) Leq=73.0 dB LS90=72.8 dB Leq=73.0 dB LS90=72.8 dB

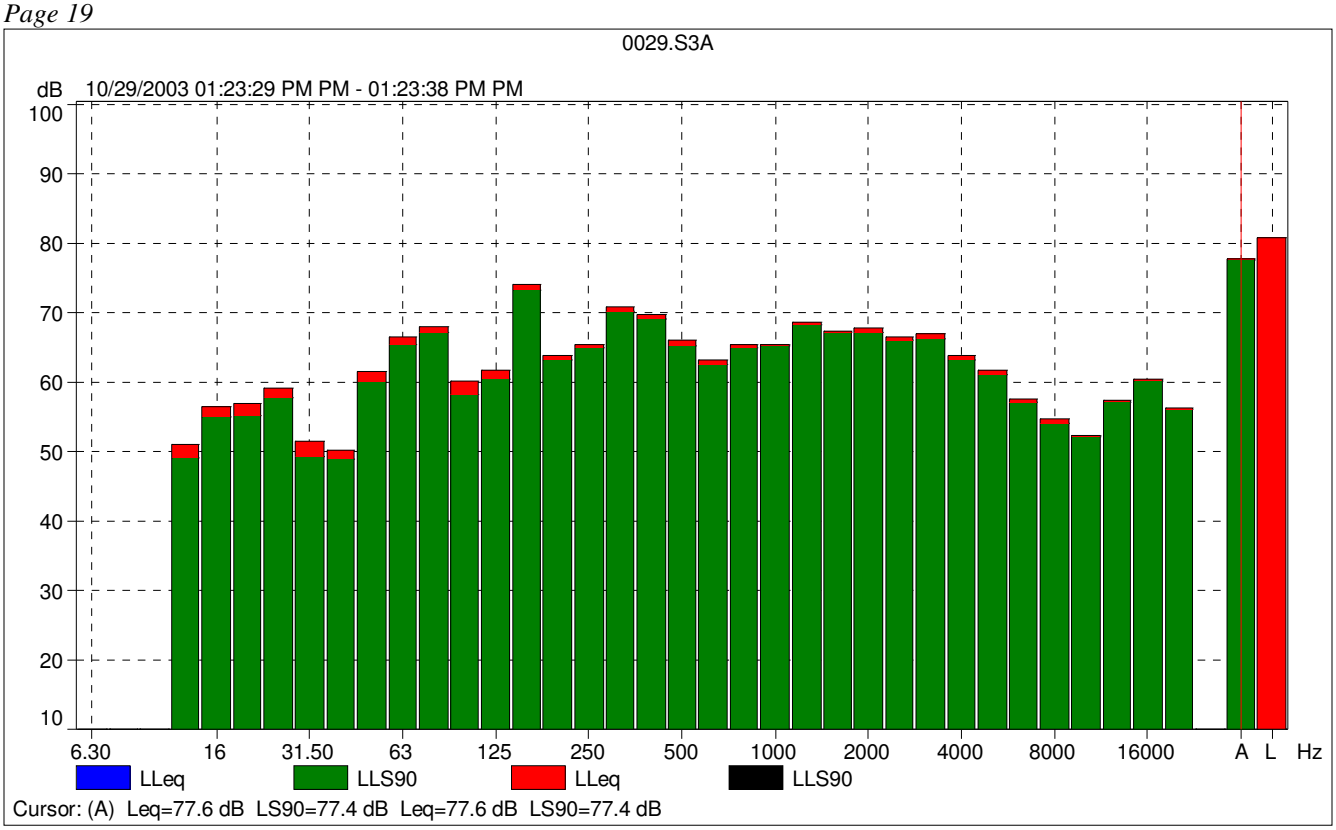

0024.S3A
dB 10/29/2003 01:19:24 PM PM - 01:19:34 PM PM
100
90
80
70
60
50
40
30
20
10
6.30
16
31.50
63
125
250
500
1000
2000
4000
8000
16000
A L Hz
LLeq
LLS90
LLeq
LLS90
Cursor: (A) Leq=72.0 dB LS90=71.8 dB Leq=72.0 dB LS90=71.8 dB

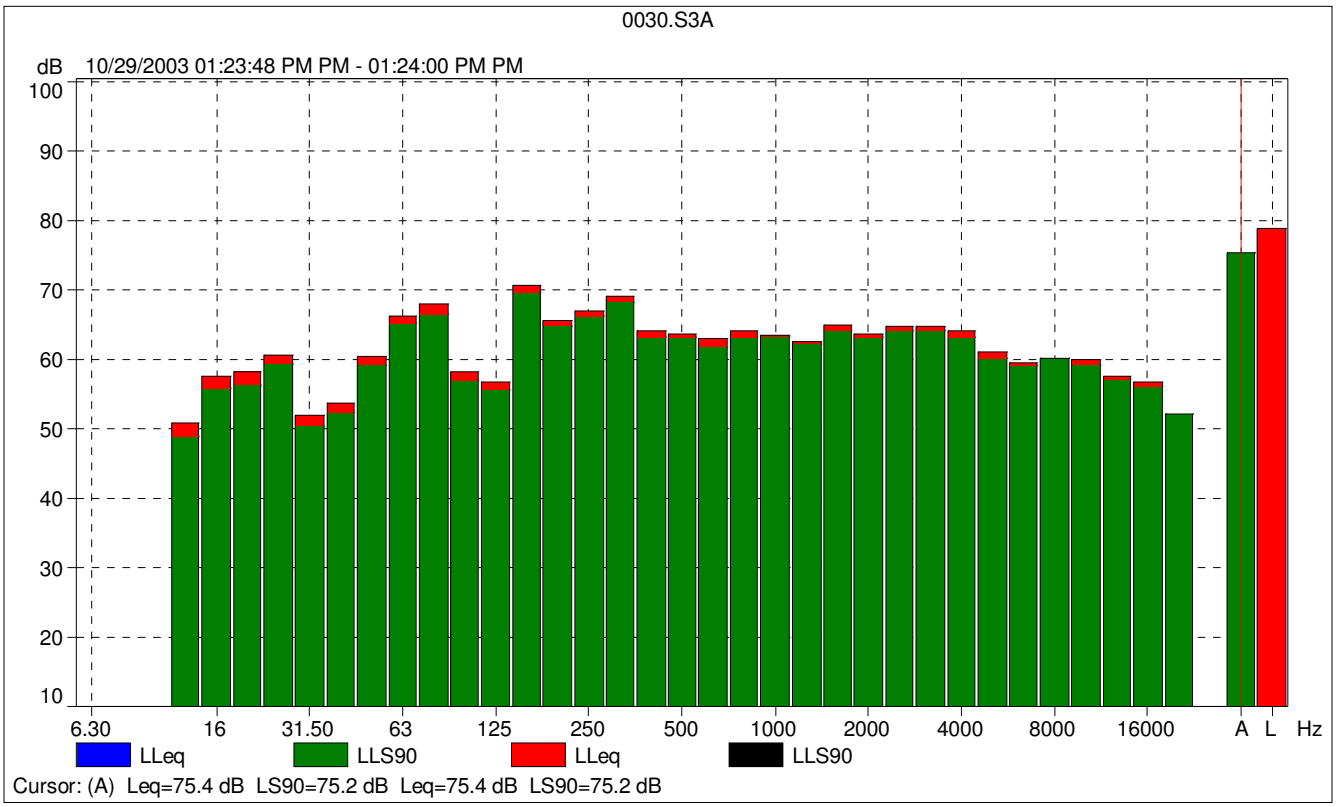

0025.S3A
dB 10/29/2003 01:19:53 PM PM - 01:20:05 PM PM
100
90
80
70
60
50
40
30
20
10
6.30
16
31.50
63
125
250
500
1000
2000
4000
8000
16000
A L Hz
LLeq
LLS90
LLeq
LLS90
Cursor: (A) Leq=73.6 dB LS90=73.4 dB Leq=73.6 dB LS90=73.4 dB

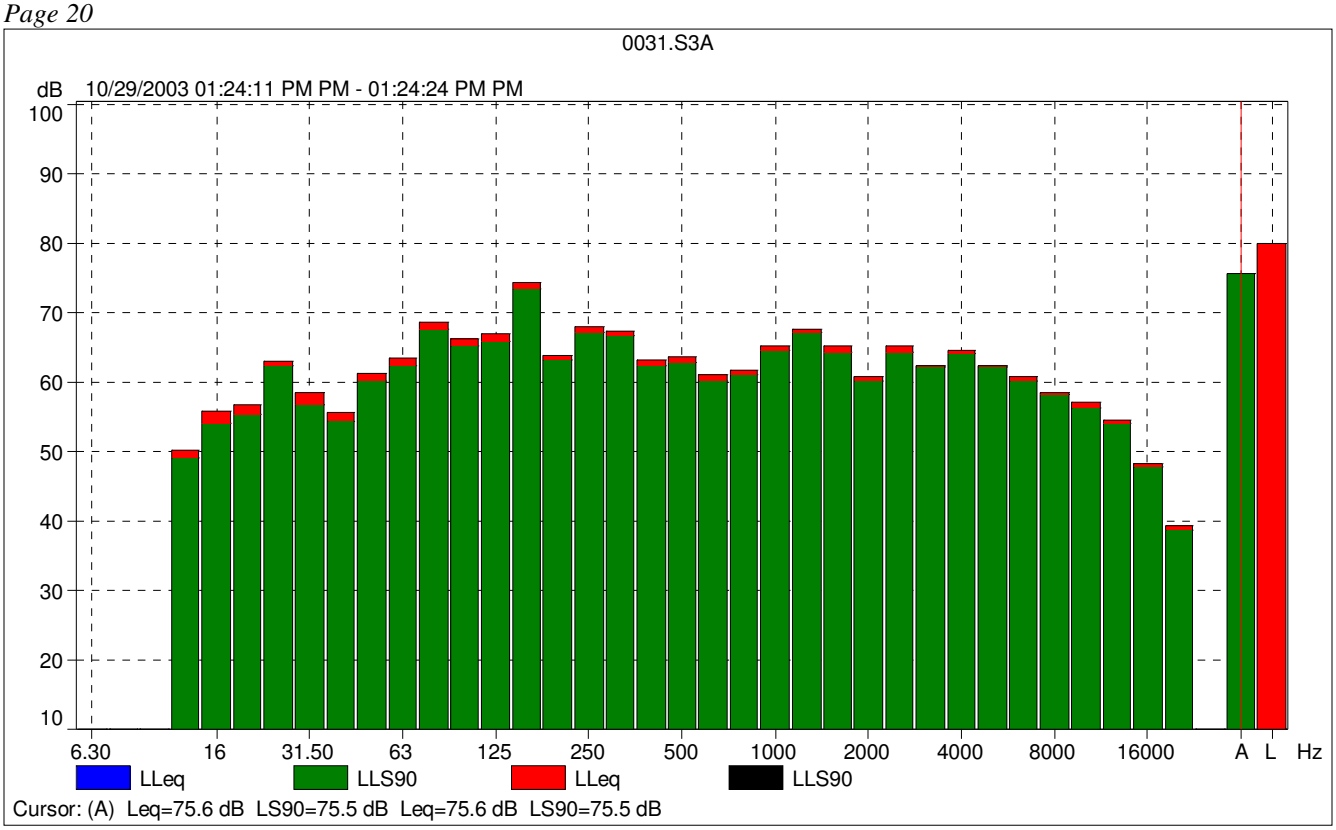

0026.S3A
dB 10/29/2003 01:20:20 PM PM - 01:20:35 PM PM
100
90
80
70
60
50
40
30
20
10
6.30
16
31.50
63
125
250
500
1000
2000
4000
8000
16000
A L Hz
LLeq
LLS90
LLeq
LLS90
Cursor: (A) Leq=69.7 dB LS90=69.6 dB Leq=69.7 dB LS90=69.6 dB

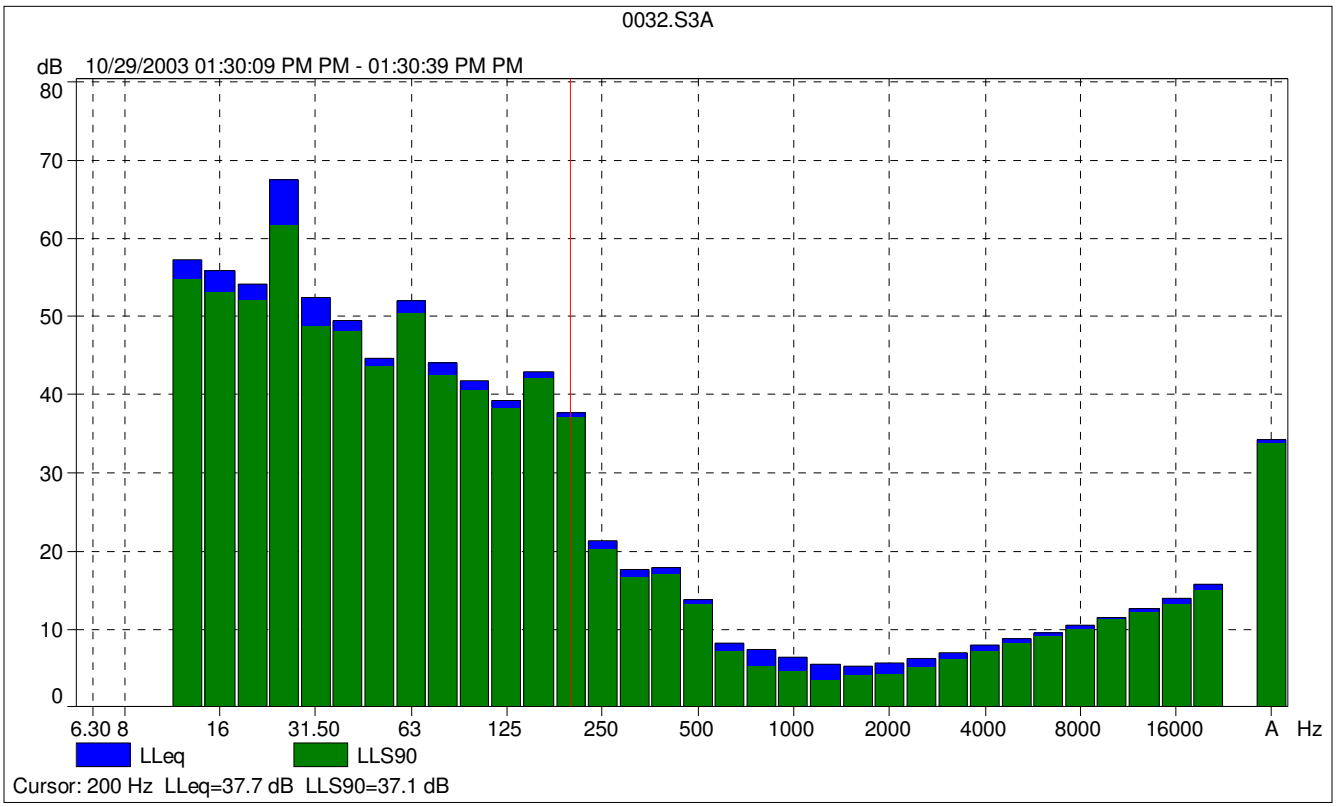

0027.S3A
dB
10/29/2003 01:22:42 PM PM - 01:22:53 PM PM
100
90
80
70
60
50
40
30
20
10
6.30
16
31.50
63
125
250
500
1000
2000
4000
8000
16000
A
L
Hz
LLeq
LLS90
LLeq
LLS90
Cursor: 2000 Hz LLeq=59.8 dB LLS90=59.1 dB LLeq=59.8 dB LLS90=59.1 dB

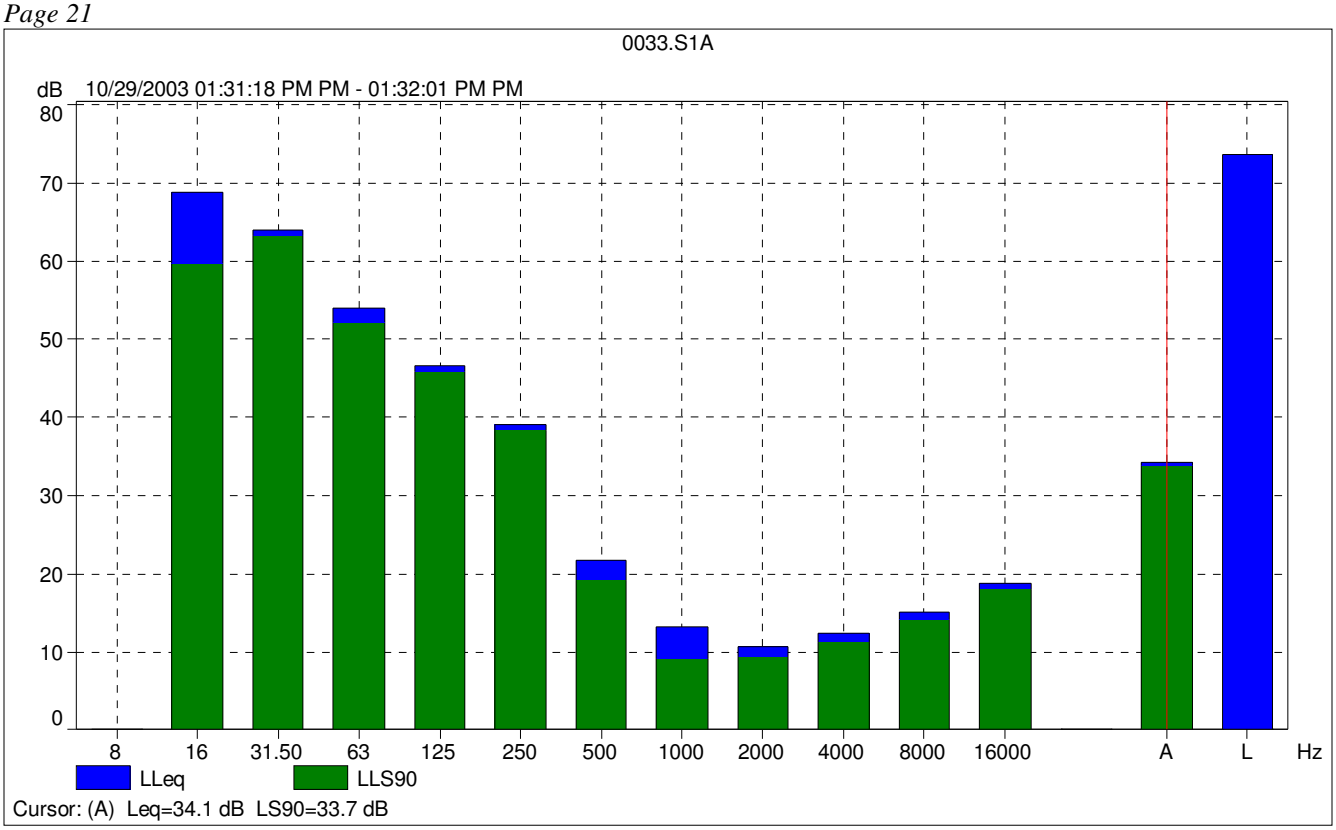

0028.S3A
dB
10/29/2003 01:23:07 PM PM - 01:23:18 PM PM
100
90
80
70
60
50
40
30
20
10
6.30
16
31.50
63
125
250
500
1000
2000
4000
8000
16000
A
L
Hz
LLeq
LLS90
LLeq
LLS90
Cursor: (A) Leq=74.9 dB LS90=74.8 dB Leq=74.9 dB LS90=74.8 dB

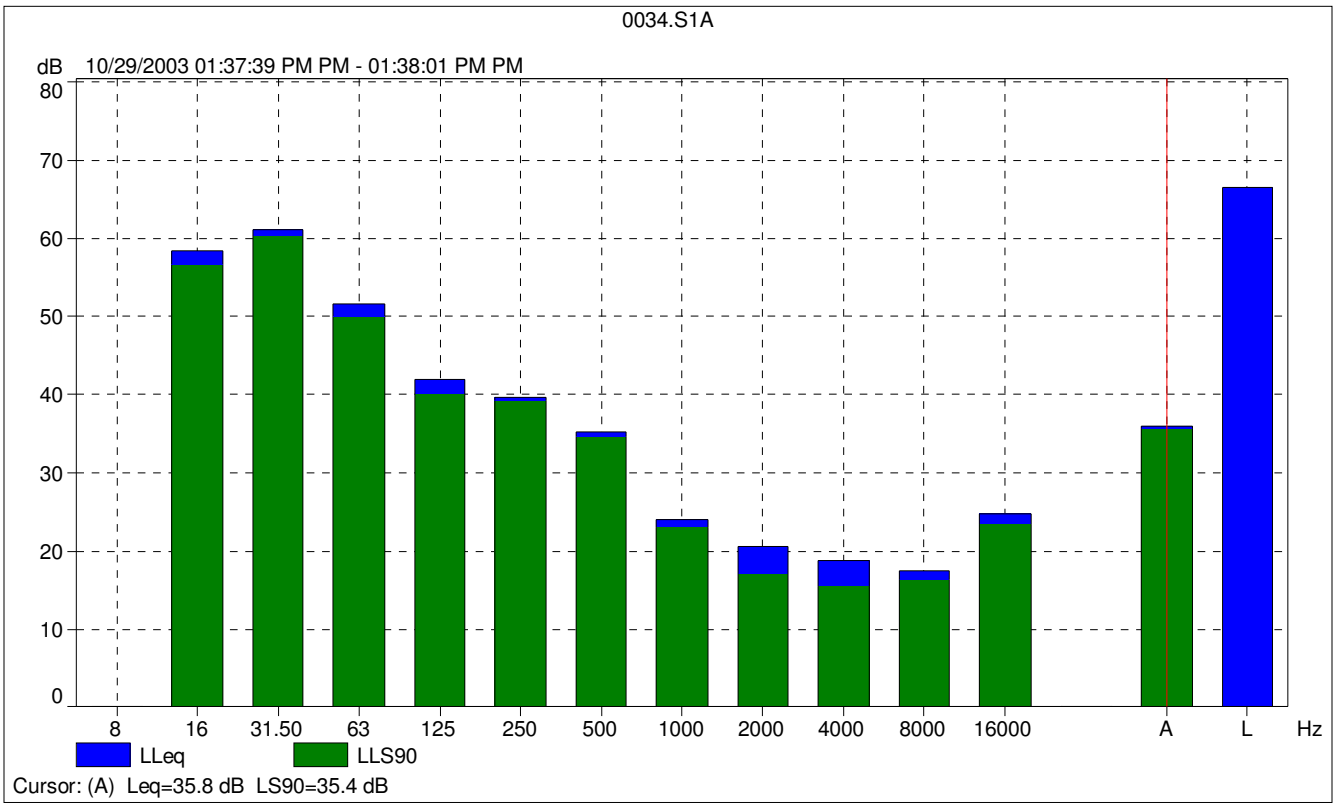

0029.S3A
dB 10/29/2003 01:23:29 PM PM - 01:23:38 PM PM
100
90
80
70
60
50
40
30
20
10
6.30
16
31.50
63
125
250
500
1000
2000
4000
8000
16000
A L Hz
LLeq
LLS90
LLeq
LLS90
Cursor: (A) Leq=77.6 dB LS90=77.4 dB Leq=77.6 dB LS90=77.4 dB

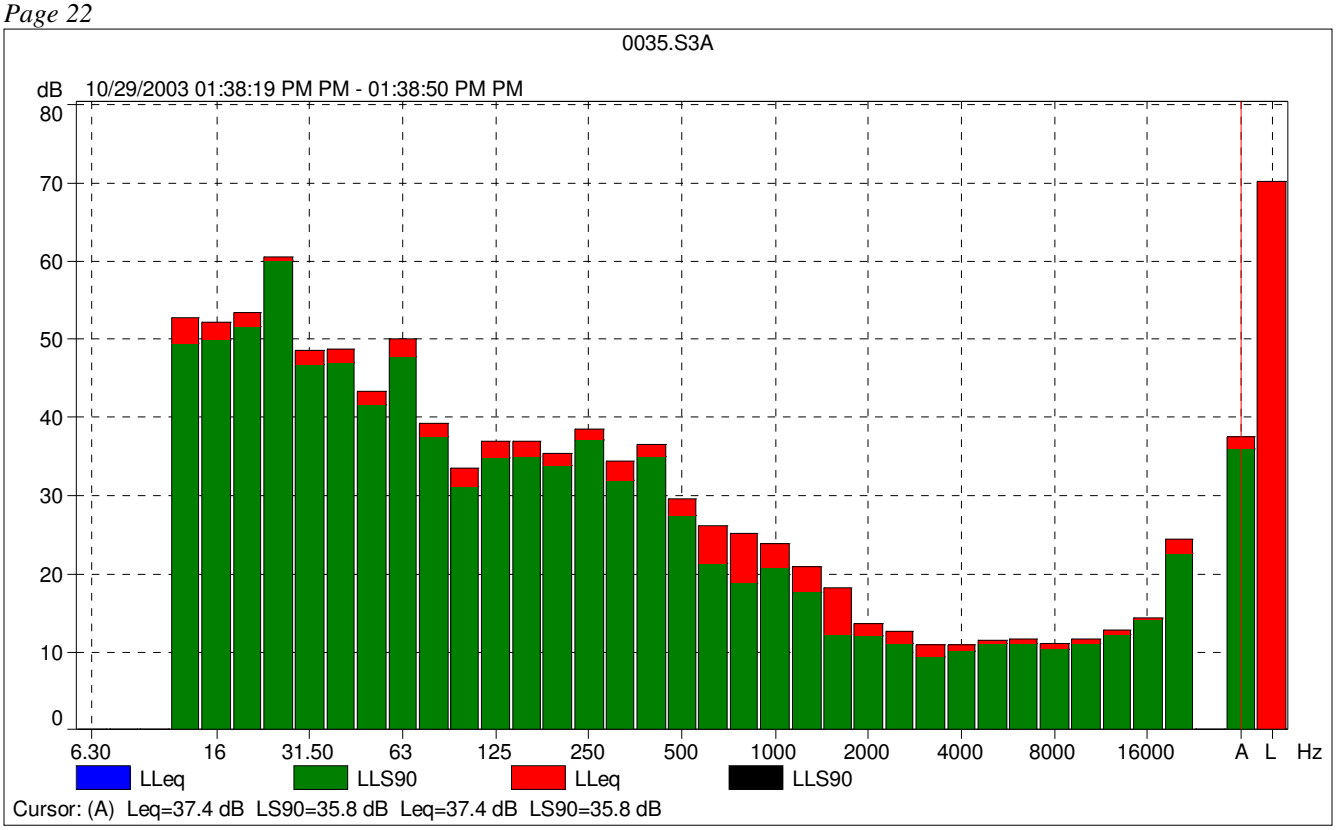

0030.S3A
dB 10/29/2003 01:23:48 PM PM - 01:24:00 PM PM
100
90
80
70
60
50
40
30
20
10
6.30
16
31.50
63
125
250
500
1000
2000
4000
8000
16000
A L Hz
LLeq
LLS90
LLeq
LLS90
Cursor: (A) Leq=75.4 dB LS90=75.2 dB Leq=75.4 dB LS90=75.2 dB


0031.S3A
dB 10/29/2003 01:24:11 PM PM - 01:24:24 PM PM
100
90
80
70
60
50
40
30
20
10
6.30
16
31.50
63
125
250
500
1000
2000
4000
8000
16000
A L Hz
LLeq
LLS90
LLeq
LLS90
Cursor: (A) Leq=75.6 dB LS90=75.5 dB Leq=75.6 dB LS90=75.5 dB


0032.S3A
dB 10/29/2003 01:30:09 PM PM - 01:30:39 PM PM
80
70
60
50
40
30
20
10
0
6.30 8
16
31.50
63
125
250
500
1000
2000
4000
8000
16000
A Hz
LLeq
LLS90
Cursor: 200 Hz LLeq=37.7 dB LLS90=37.1 dB


0033.S1A
dB 10/29/2003 01:31:18 PM PM - 01:32:01 PM PM
80
70
60
50
40
30
20
10
0
8
16
31.50
63
125
250
500
1000
2000
4000
8000
16000
A
L
Hz
LLeq
LLS90
Cursor: (A) Leq=34.1 dB LS90=33.7 dB


0034.S1A
dB 10/29/2003 01:37:39 PM PM - 01:38:01 PM PM
80
70
60
50
40
30
20
10
0
8
16
31.50
63
125
250
500
1000
2000
4000
8000
16000
A
L
Hz
LLeq
LLS90
Cursor: (A) Leq=35.8 dB LS90=35.4 dB


0035.S3A
dB
10/29/2003 01:38:19 PM PM - 01:38:50 PM PM
80
70
60
50
40
30
20
10
0
6.30
16
31.50
63
125
250
500
1000
2000
4000
8000
16000
A
L
Hz
LLeq
LLS90
LLeq
LLS90
Cursor: (A) Leq=37.4 dB LS90=35.8 dB Leq=37.4 dB LS90=35.8 dB

APPENDIX B

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November 14, 2003

M E M O R A N D U M

TO: DAB Subcommittee – Evaluation Working Group (EWG)

FROM: D. Layer

SUBJECT: FM IBOC system 3rd generation hardware ("Gen 3") re-test

Given below is a summary of the test plan agreed to by the EWG at the 11/12/03 Evaluation Working Group meeting, for the limited re-testing of the iBiquity FM IBOC 3rd generation hardware:

System description: in the Gen 3 test report document, iBiquity will certify that the 3rd generation system hardware tested fully complies with Appendix A of the FM test data report submitted to the NRSC in August 2001, and that the only significant functional changes made between the hardware originally tested by the NRSC and the 3rd generation system undergoing this re-test are:

- replacement of AAC audio codec with HDC audio codec;
- new RF front-end in iBiquity prototype IBOC receiver.

Baseline test procedure: IBOC laboratory test procedures – FM band, rev. 19g, February 6, 2002 (only tests I, B.1 and B.2 are performed for the Gen 3 test). Audio cut list (pg. 2 of this memo) is taken from "*Proposal for Subjective Evaluation of Generation 3 HD Radio Hardware*," prepared for the National Radio Systems Committee and iBiquity Digital Corporation, Ellyn Sheffield, Ph.D., Sheffield Audio Consulting.

NRSC observer: start-to-finish, omnipresent NRSC observation will be required for the Gen 3 tests to allow the NRSC to evaluate the resulting data.

IBOC quality (Test I): see revised procedure (attached). This test will be conducted three times, each time at a different main channel audio bit rate. The three rates to be used are 96 kbps, 64 kbps, and 32 kbps. Audio selections and processor settings will be per Appendix I to iBiquity memo to TPWG dated 1/25/02.

AWGN (Test B.1): see revised procedure (attached). Note that analog reference recordings will be made using all four NRSC analog test receivers at the operating point established in step 2 of test B.1. This test is performed for an audio bit rate of 96 kbps only.

Multipath with noise (Test B.2): see revised procedure (attached). Test bed calibration with multipath simulator installed must be checked prior to running this test. Note that the urban slow multipath fading scenario will not be done. This test is performed for an audio bit rate of 96 kbps only.

(attachments)

Table 4: FM Digital Post-Processor Settings

ARTIST	ALBUM TITLE	SONG TITLE	Digital Post-processor settings	TEST
Bach	Brandenburg Concerto #5, D Major	Allegro	Orban 8400-HD-20-01	Both
Bizet	Carmen		Orban 8400-HD-20-01	Unimpaired
Enya	Shepherd Moons	Angeles	Orban 8400-HD-20-01	Unimpaired
Eric Clapton	Best of Eric Clapton	Change the World	No Processing	Unimpaired
Paula Cole	Harbinger	Happy Home	No Processing	Impaired
Crowded House	Woodface	Weather With You	No Processing	Impaired
Earth, Wind and Fire	Greatest Hits	Let's Groove	No Processing	Unimpaired
Fagen	The Nightfly	IGY	No Processing	Impaired
Glockenspeil	SQAM Disc		No Processing	Unimpaired
Amy Grant	Heart in Motion	Baby, Baby	No Processing	Unimpaired
Handel	Messiah	Hallelujah	Orban 8400-HD-20-01	Both
Medewski, Martin & Wood	Shack Man	Hermeto's Daydream	No Processing	Unimpaired
Moulton Labs	Critical Listening Excerpts	Kyoko Saito	Orban 8400-HD-20-01	Unimpaired
Prince			No Processing	Impaired
Persian Music			No Processing	Both
Paul Simon	Rhythm of the Saints	Can't Run But	No Processing	Unimpaired
Tchaikovski	1812 Overture	Track 17	Orban 8400-HD-20-01	Both
Randy Travis	A Man Ain't Made of Stone	A Heartache In the Works	No Processing	Unimpaired
Trumpet	SQAM Disc		No Processing	Unimpaired
English Woman	SQAM Disc		Omnia AC	Both
Tom Brokaw	The Greatest Generation		Omnia AC	Both
English Male	SQAM Disc		Omnia AC	Both

Table C-1 Analog FM Processor: Light Preset

Processor Name: Cutting Edge Omnia 4500 Preset Name: Light			
Parameter	**Value**	**Parameter**	**Value**
WB-AGC	IN	**LF-LIMITER**	
AGC Drive	(+)6.0	Drive	0.0
Attack	3	Threshold	(+)2.0
Release	0	Attack	3
Make-Up Gain	1	Release	2
Gate Thresh	4	Hold Thresh	4
BASS		**MF-LIMITER**	
Deep Bass	0.0	Drive	0.0
Phat Bass	0.0	Threshold	0.0
		Attack	3
WARMTH	0.0	Release	1
		Hold Thresh	2
X-OVER			
Low Gain	0.0	**PR-LIMITER**	
Mid Gain	0.0	Drive	0.0
Pres Gain	(+)1.0	Threshold	0.0
High Gain	(+)1.5	Attack	3
		Release	2
LF-AGC		Hold Thresh	4
Attack	2		
Release	0	**HF-LIMITER**	
Make-Up Gain	2	Drive	(+)1.0
Gate Thresh	3	Threshold	(-)7.5
RTP Speed	Slow	Attack	3
RTP Level	(-)10	Release	2
		Hold Thresh	1
MF-AGC			
Attack	3	**MIXER**	
Release	0	Low Band	0.0

Processor Name: Cutting Edge Omnia 4500 Preset Name: Light			
Make-Up Gain	2	Mid Band	0.0
Gate Thresh	3	Pres Band	(-)4.0
RTP Speed	Slow	High Band	(-)5.5
RTP Level	(-)10		
		CLIPPER	
PR-AGC		Drive	(+)0.5
Attack	3		
Release	0	**COMP CLIP**	
Make-Up Gain	3	Drive	0.0
Gate Thresh	2		
RTP Speed	Slow		
RTP Level	(-)10		
HF-AGC			
Attack	4		
Release	1		
Make-Up Gain	3		
Gate Thresh	2		
RTP Speed	Slow		
RTP Level	(-)5		

Table C-2 Analog FM Processor: Medium Preset

Processor Name: Cutting Edge Omnia 4500 Preset Name: Medium			
Parameter	**Value**	**Parameter**	**Value**
WB-AGC	IN	**LF-LIMITER**	
AGC Drive	(+)6.0	Drive	(+)1.5
Attack	3	Threshold	(+)1.5
Release	0	Attack	4
Make-Up Gain	1	Release	2
Gate Thresh	4	Hold Thresh	4
BASS		**MF-LIMITER**	
Deep Bass	(+)4.0	Drive	(+)1.5
Phat Bass	(+)2.0	Threshold	0.0
		Attack	3
WARMTH	(+)1.0	Release	1
		Hold Thresh	3
X-OVER			
Low Gain	(+)2.0	**PR-LIMITER**	
Mid Gain	(+)2.0	Drive	(+)1.5
Pres Gain	(+)3.0	Threshold	0.0
High Gain	(+)4.0	Attack	3

Processor Name: Cutting Edge Omnia 4500 Preset Name: Medium			
		Release	2
LF-AGC		Hold Thresh	2
Attack	2		
Release	0	**HF-LIMITER**	
Make-Up Gain	2	Drive	(+)2.0
Gate Thresh	3	Threshold	(-)7.5
RTP Speed	Slow	Attack	3
RTP Level	(-)10	Release	2
		Hold Thresh	1
MF-AGC			
Attack	2	**MIXER**	
Release	2	Low Band	0.0
Make-Up Gain	2	Mid Band	0.0
Gate Thresh	3	Pres Band	(-)4.0
RTP Speed	Slow	High Band	(-)5.0
RTP Level	(-)10		
		CLIPPER	
PR-AGC		Drive	(+)1.0
Attack	2		
Release	2	**COMP CLIP**	
Make-Up Gain	3	Drive	(+)1.0
Gate Thresh	2		
RTP Speed	Slow		
RTP Level	(-)10		
HF-AGC			
Attack	3		
Release	2		
Make-Up Gain	3		
Gate Thresh	2		
RTP Speed	Slow		
RTP Level	(-)5		

Table C-3 Analog FM Processor: Hard Preset

Processor Name: Cutting Edge Omnia 4500 Preset Name: Hard			
Parameter	**Value**	**Parameter**	**Value**
WB-AGC	IN	**LF-LIMITER**	
AGC Drive	(+)6.0	Drive	(+)2.5
Attack	3	Threshold	(+)1.0
Release	0	Attack	4
Make-Up Gain	1	Release	2
Gate Thresh	4	Hold Thresh	4
BASS		**MF-LIMITER**	

Processor Name: Cutting Edge Omnia 4500 Preset Name: Hard			
Deep Bass	(+)6.0	Drive	(+)2.5
Phat Bass	(+)3.0	Threshold	0.0
		Attack	4
WARMTH	(+)1.0	Release	3
		Hold Thresh	3
X-OVER			
Low Gain	(+)3.5	**PR-LIMITER**	
Mid Gain	(+)3.5	Drive	(+)2.5
Pres Gain	(+)3.5	Threshold	0.0
High Gain	(+)4.0	Attack	4
		Release	3
LF-AGC		Hold Thresh	2
Attack	2		
Release	0	**HF-LIMITER**	
Make-Up Gain	2	Drive	(+)3.0
Gate Thresh	3	Threshold	(-)7.5
RTP Speed	Slow	Attack	3
RTP Level	(-)10	Release	3
		Hold Thresh	1
MF-AGC			
Attack	2	**MIXER**	
Release	4	Low Band	(+)0.5
Make-Up Gain	4	Mid Band	(+)0.5
Gate Thresh	3	Pres Band	(-)4.0
RTP Speed	Slow	High Band	(-)5.0
RTP Level	(-)10		
		CLIPPER	
PR-AGC		Drive	(+)1.5
Attack	2		
Release	4	**COMP CLIP**	
Make-Up Gain	4	Drive	(+)1.5
Gate Thresh	2		
RTP Speed	Slow		
RTP Level	(-)10		
HF-AGC			
Attack	3		
Release	2		
Make-Up Gain	3		
Gate Thresh	1		
RTP Speed	Slow		
RTP Level	(-)5		

IBOC LABORATORY TEST PROCEDURES – FM BAND DIGITAL QUALITY					
Test Group	Test & Impairment	TEST DESCRIPTION Note: 1. Analog reference recordings will be obtained using non-IBOC exciter. (For Gen 3 testing, the analog reference recordings obtained during the Gen 2 tests will be utilized.) 2. Audio processors will be used in both IBOC and analog signal paths (settings for analog and digital signal paths will vary based upon audio selection and may be different from one another). 3. This test will be conducted three times, each time at a different main channel audio bit rate. The three rates to be used are 96 kbps, 64 kbps, and 32 kbps.	Desired Signal Level	Type of Evaluation	Test Results & Data to be Recorded
I IBOC quality	1 Quality transmission test	1. Tests will be conducted using the audio quality selections. 2. Each of the selections will be transmitted through the IBOC system without impairment and recorded for subjective evaluation. 3. For each measurement point, the mode signal status will be recorded. 4. An analog reference recording will be made using all four NRSC analog test receivers for each audio quality selection.	S	Objective	Mode signal status of system during recording of audio selections
				Subjective	Subjective rating for each audio quality selection recorded (using IBOC, all four analog receivers) as well as for source material. For IBOC recordings, only 96 kbps, 64 kbps to be subjectively evaluated.

IBOC LABORATORY TEST PROCEDURES – FM BAND
DIGITAL PERFORMANCE

Test Group	Test & Impairment	TEST DESCRIPTION Notes: 1. For urban slow multipath tests, the desired multipath audio selections will be repeated as required to complete a full fading cycle on the MP simulator. 2. The audio will be restarted for each test. 3. The analog reference recordings specified in step B.2.5 will be made with the IBOC digital sidebands removed from the desired signals.	Desired Signal Level	Type of Evaluation	Test Results Data to be Recorded
B AWGN	1 Linear channel	1. The level of AWGN corresponding to system point of blend will be established. 2. The desired impairment audio segments will be recorded with the AWGN set at a level 2 dB below (i.e. before) the point of blend. 3. The BLER will be recorded with the AWGN set at a level 4 dB below (i.e. before) the point of blend, then with the AWGN level increased in 1 dB steps until at the point of blend, then at 2 dB and 4 dB above (i.e. after) the point of blend.	M	Objective	Cd/No, BLER for each measurement point (with point of blend identified)
				Subjective	Subjective impairment rating for recording made in step 2
	2 Multipath fading channel	1. This test will be conducted four times, each with a different Rayleigh multipath scenario. The multipath scenarios will be those specified on the "general comments" page of this procedure. Each cut will be recorded for subjective assessment. 2. For each multipath scenario, the level of AWGN corresponding to system point of blend will be established. 3. The desired impairment audio segments will be recorded with the AWGN set at a level 8 dB below (i.e. before) the point of blend. 4. The BLER will be recorded with the AWGN set at a level 8 dB below (i.e. before) the point of blend, then with the AWGN level increased in 2 dB steps until 6 dB above (i.e. after) the point of blend. 5. An analog reference recording will be made using NRSC analog test receivers #1 and #2 (automobile receivers) for each multipath scenario, at the measurement point of step 3.	M	Objective	Cd/No, BLER for each measurement point (with point of blend identified)
				Subjective	Subjective impairment rating for each multipath scenario and audio cut, for IBOC digital and analog reference recordings made in steps 2 and 5

APPENDIX C

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November 14, 2003

M E M O R A N D U M

TO: DAB Subcommittee – Evaluation Working Group (EWG)

FROM: D. Layer

SUBJECT: AM IBOC system 3rd generation hardware ("Gen 3") re-test

Given below is a summary of the test plan agreed to by the EWG at the 11/12/03 Evaluation Working Group meeting, for the limited re-testing of the iBiquity AM IBOC 3rd generation hardware:

System description: in the Gen 3 test report document, iBiquity will certify that the 3rd generation system hardware tested fully complies with Appendix A of the AM test data report submitted to the NRSC on January 4, 2002, and that the only significant functional changes made between the hardware originally tested by the NRSC and the 3rd generation system undergoing this re-test are:

- replacement of AAC audio codec with HDC audio codec;
- new RF front-end in iBiquity prototype IBOC receiver.

Baseline test procedure: IBOC laboratory test procedures – AM band, rev. 6d, February 6, 2002 (only tests G and B.1 are performed for the Gen 3 test). Audio cut list (pg. 2 of this memo) is taken from "*Proposal for Subjective Evaluation of Generation 3 HD Radio Hardware*," prepared for the National Radio Systems Committee and iBiquity Digital Corporation, Ellyn Sheffield, Ph.D., Sheffield Audio Consulting.

NRSC observer: start-to-finish, omnipresent NRSC observation will be required for the Gen 3 tests to allow the NRSC to evaluate the resulting data.

IBOC quality (Test G): see revised procedure and list of audio selections and processor settings (attached). This test will be conducted twice – once with the system operating in "enhanced" digital audio mode (36 kbps) and once with the system operating in "core" digital audio mode (20 kbps).

AWGN (Test B.1): see revised procedure (attached). Note that analog reference recordings will be made using all four NRSC analog test receivers at the operating points established in steps 3 and 4 of test B.1.

(attachments)

Table 1: Samples and post-processor settings for AM Tests

ARTIST	ALBUM TITLE	SONG TITLE	Digital Post-processor settings	TEST
Bizet	Carmen		Orban 8400-HD-20-01	Unimpaired
Eric Clapton	Best of Clapton	Change the World	No Processing	Unimpaired
Crosby, Stills, Nash, & Young	Looking Forward	Sanibel	No Processing	Unimpaired
EWF	Greatest Hits	Let's Groove	No Processing	Unimpaired
Handel	Messiah	Hallelujah	Orban 8400	Unimpaired
Jaques Ibert	Summertime Music for Oboe	Entr'acte	Orban 8400	Unimpaired
Moulton Labs	CriticalListening Excerpts	Kyoko Saito	Orban 8400-HD-20-01	Unimpaired
REO Speedwagon	Hi Fidelity	Keep on Loving You	No Processing	Unimpaired
Randy Travis	A Man Ain't Made of Stone	A Heartache In the Works	No Processing	Unimpaired
Suzanne Vega	Nine Objects of Desire	Caramel	No Processing	Unimpaired
Ballet Woman	Voice Over	From WTOP	No Processing	Unimpaired
Camera	Voice Over	From WTOP	No Processing	Unimpaired
From Richmond	Voice Over	From WTOP	No Processing	Unimpaired
Riverdance	Voice Over	From WTOP	No Processing	Both
Santana	Supernatural	Smoth	Orban 8400-HD-20-01	Impaired
Ibert	Summertime Music for Oboe	Entr'acte	Orban 8400-HD-20-01	Impaired
Fleetwood Mac	Tango in the Night	IGY	No Processing	Impaired
Imagine	Voice Over		No Processing	Impaired
Debussy	String Quartet in g minor	Anime et tres decide	Orban 8400-HD-20-01	Impaired
FemaleB2	Brown	The Switch	Orban 8400-HD-20-01	Impaired
FemaleA1	Austen	Northanger Abbey	Orban 8400-HD-20-01	Both
FemaleC10	Scottline	The Vendetta Defense	Orban 8400-HD-20-01	Unimpaired
MaleA1	Coonts	Hong Kong	Orban 8400-HD-20-01	Unimpaired
MaleB4	Glenn	John Glenn: A Memoir	Orban 8400-HD-20-01	Unimpaired

The Optimod 9200 will be configured as follows:

(The AES/EBU outputs of the Orban will be connected to the Digital Input of the LynxOne audio card for recordings. Cooledit Pro will be used to perform the recordings. Once the processed recordings are completed, they will each be cropped to the section of interest. These cropped files are then written to CD in stereo 16 bit, 44.1 kHz format for use in the subjective testing.)

Voice cuts:

Processing:
- Preset: News
- HF Curve: NRSC

Setup:
- INPUT: Digital
- POS PEAK: 125%

BANDWIDTH:
- HP FLTR: 50 Hz
- LP FLTR NRSC or 4.5 kHz

Digital Input:
- DI MODE: DIG-L
- DI REV VU: -11.0 dBFS
- DI REF PPM: -3.0 dBFS

Digital Output:
- DO 100%: -3.6 dBFS
- DO RATE: 44.1 kHz
- DO SYNC: Internal
- HF DELAY: Off
- HF Shelf: off

Classical cuts:

Processing:
- Preset: Fine arts
- HF Curve: NRSC

Setup:
- INPUT: Digital
- POS PEAK: 125%

BANDWIDTH:
- HP FLTR: 50 Hz
- LP FLTR NRSC or 4.5 kHz

Digital Input:
- DI MODE: DIG-L
- DI REV VU: -11.0 dBFS
- DI REF PPM: -3.0 dBFS

Digital Output:
- DO 100%: -3.6 dBFS
- DO RATE: 44.1 kHz
- DO SYNC: Internal
- HF DELAY: Off
- HF Shelf: off

Rock and Voice-over cuts:

Processing:
- Preset: Music Heavy
- HF Curve: NRSC

Setup:
- INPUT: Digital
- POS PEAK: 125%

BANDWIDTH:
- HP FLTR: 50 Hz
- LP FLTR NRSC or 4.5 kHz

Digital Input:
- DI MODE: DIG-L
- DI REV VU: -11.0 dBFS
- DI REF PPM: -3.0 dBFS

Digital Output:
- DO 100%: -3.6 dBFS
- DO RATE: 44.1 kHz
- DO SYNC: Internal
- HF DELAY: Off
- HF Shelf: off

IBOC LABORATORY TEST PROCEDURES – AM BAND
DIGITAL PERFORMANCE

Test Group	Test & Impairment	TEST DESCRIPTION Notes: 1. The audio will be restarted for each test. 2. Analog reference recordings will be made using all four NRSC analog test receivers at the operating points established in steps 3 and 4 of test B.1.	Desired Signal Level	Type of Evaluation	Test Results Data to be Recorded
B Characterization of signal failure with AWGN	1 AWGN	1. The level of AWGN corresponding to system point of loss of enhanced audio will be established. 2. The level of AWGN corresponding to system point of blend will be established. 3. The desired impairment audio segments will be recorded with the AWGN set at a level 2 dB below (i.e. before) the point of loss of enhanced audio. 4. The desired impairment audio segments will be recorded with the AWGN set at a level 2 dB below (i.e. before) the point of blend. 5. The BLER will be recorded with the AWGN set at a level 2 dB below (i.e. before) the point of loss of enhanced audio, then with the AWGN level increased in 1 dB steps until at the point of blend, then at 2 dB and 4 dB above (i.e. after) the point of blend.	M	Objective	Cd/No, BLER for each measurement point (with point of loss of enhanced audio, point of blend identified)
				Subjective	Subjective impairment rating for each level of Cd/No for recordings made in steps 3 and 4

IBOC LABORATORY TEST PROCEDURES – AM BAND DIGITAL QUALITY					
Test Group	Test & Impairment	TEST DESCRIPTION Note: 1. Analog reference recordings will be obtained using an exciter which conforms to the NRSC standard AM mask (i.e. 10 kHz nominal audio bandwidth). (For Gen 3 testing, the analog reference recordings obtained during the Gen 2 tests will be utilized.) 2. Audio processors will be used in both IBOC and analog signal paths (settings for analog and digital signal paths will vary based upon audio selection and may be different from one another). 3. This test will be conducted twice – once with the system operating in "enhanced" digital audio mode (36 kbps) and once with the system operating in "core" digital audio mode (20 kbps).	Desired Signal Level	Type of Evaluation	Test Results & Data to be Recorded
G IBOC quality	1 Quality transmission test	1. Tests will be conducted using the audio quality selections. 2. Each of the selections will be transmitted through the IBOC system without impairment and recorded for subjective evaluation. 3. For each measurement point, the mode signal status will be recorded. 4. An analog reference recording will be made using all four NRSC analog test receivers for each audio quality selection. 5. A recording of each selection will also be made through an FM signal chain using the home hi-fi NRSC analog test receiver (and appropriate audio processing).	S	Objective	Mode signal status of system during recording of audio selections
				Subjective	Subjective rating for each audio quality selection recorded (using IBOC, all four analog receivers) as well as for FM recordings